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Adaptation of the Kift-Fooks lonospheric Ray-Tracing Technique to a High-Speed Digital Computer

by Douglas E. Westover and Lawrence A. Roben

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October 1963

Technical Report No. 78

Prepared under Office of Naval Research Contract Nonr-225(64), NR 088 019, and

Advanced Research Projects Agency ARPA Orders 196-62 and 196-63

DEC 28 1962

RADIOSCIENCE LABORATORY

STANFORD ELECTRONICS LABORATORIES

STANFORD UNIVERSITY · STANFORD, CALIFORNIA



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ADAPTATION OF THE KIFT-FOOKS IONOSPHERIC RAY-TRACING TECHNIQUE TO A HIGH-SPEED DIGITAL COMPUTER

bу

Douglas E. Westover and Lawrence A. Roben

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Radioscience Laboratory
Stanford Electronics Laboratories
Stanford University Stanford, California

ABSTRACT

This report describes a modified ray-tracing technique used in the synthesis of oblique-incidence, step-frequency ionograms. Ionograms of this type are obtained experimentally to aid in the real-time selection of frequencies for point-to-point communications and propagation studies. When it is desirable to identify the modes of propagation, computer-calculated ray tracings have proved quite valuable.

The Kift-Fooks ray-tracing technique was chosen because it is a rapid program capable of tracing rays when only a minimum of ionospheric data is available. One could utilize this technique in the analysis of propagation data either by synthesizing an oblique-incidence ionogram for direct comparison with experimentally observed results or by comparing plots of maximum usable frequency (predicted) with receiving-station log sheets. The details of the computer program are included with instructions that may be used as a guide by anyone familiar with computers and programming operations to perform his own calculations.

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LIST OF SYMBOLS

- d distance to any point along the great-circle path
- f frequency
- f_h gyro frequency
- \mathbf{f}_{0} critical frequency of a layer
- f E FOE = critical frequency of the E layer
- f Fl FOF1 = critical frequency of the Fl layer
- $\widetilde{f_0}$ F2 F0F2 = critical frequency of the F2 layer
- f_0E_S FOES = critical frequency of the ES layer
 - h height
 - h height at the bottom of a parabolic layer
 - h, height of reflection
 - h_{m} height of the maximum electron density of a layer
 - $h_{m}^{\ E}$ height of the maximum electron density of the E layer
- $h_{m}^{\ Fl}$ height of the maximum electron density of the Fl layer
- $h_{m}F2$ HT FOF2 = height of the maximum electron density of the F2 layer
 - i angle between ray path and vertical at any point along the path
 - p' time delay
 - x ratio of the F2 4000 MUF to the f_{o} F2
 - D distance ray propagates
 - DB attenuation due to D-layer absorption
- F2 4000 MUF maximum usable frequency for 1-hop F2-layer propagation
 - LOF lowest observed frequency
 - MOF maximum observed frequency
 - M3000 ratio of the F2 3000 MUF to the foF2
 - N number of ray passages through the D layer

- R radius of the earth
- SSN sunspot number
 - T time in hours (universal time)
 - Y semi thickness of a parabolic layer
- $\mathbf{Y}_{\mathbf{m}}^{\mathbf{E}}$ semi thickness of the parabolic E layer
- Y_mFl semi thickness of the parabolic Fl layer
 - α bearing of receiver from transmitter (degrees East of North)
 - β take-off angle (above the horizon)
 - θ_{0} longitude of transmitter
 - θ_{γ} longitude of point on path
 - θ_{2} longitude of the sun
 - λ latitude of transmitter
 - A latitude of point on path
 - $\lambda_{\mathfrak{H}}$ declination of sun
 - φ_{o} φ_{o} = angle of incidence, measured from vertical, at the bottom of the ionosphere
 - $\phi_{\mathbf{r}}$ = angle of incidence, measured from vertical, at the real height of reflection
 - \emptyset_{D} Ψ_{D} = angle of incidence, measured from vertical, at the bottom of the D layer
 - χ solar zenith angle
 - △ take off angle (above the horizon)
 - △D ground distance for a ray passing through a layer
 - ΔP' virtual distance along a ray passing through a layer

ACKNOWLEDGMENTS

The suggestions of Mr. F. Kift and Dr. G. Fooks played an important part in the beginning of this work and are gratefully acknowledged. Thanks are also due to the staff of the Radioscience Laboratory of Stanford University and to its Director, Professor O. G. Villard, Jr., for their assistance, guidance, and continued helpfulness.

Digital computations were partially financed under NSF-GP948, a grant which has materially contributed to the excellence of the Stanford Computation Center.

1. INTRODUCTION

In an effort to understand better the propagation characteristics associated with fixed-frequency transmissions over a long (8000-km), east-west path (i.e., Hawaii to Massachusetts), it was decided to instrument this path with a step-frequency (4-64-Mc) transmitter and a synchronized receiver. With the above equipment operating on a round-the-clock basis, it was hoped that records could be obtained that would permit deduction of the mode structure and apparent ray path of the propagating signals.

Examination of the records taken on this path, soon indicates that the usual simplifying assumptions (such as a uniform ionosphere over the entire path) are often not representative of what is happening. The path, 8000 km long, is just on the edge of the normally assumed "allowable" two-hop, F2-layer propagation. Records show that the 2F2 mode propagates for only short periods around noon and midnight, local time, at the midpoint of the path. At other times (especially sunrise and sunset), the progressive change across the path from a daytime ionosphere (with E, F1, and F2 layers) to a nighttime ionosphere (F2 layer only) produces a bewildering variety of propagation modes. Analysis soon becomes fairly complex. To assist in the understanding of the mode structure, it was felt that a ray-tracing program that simulated the experimental data would help.

form will help in understanding the type of information that would be desirable from computed ray tracings. The experimental data were obtained in the following way. The transmitter and receiver include electronically tuned and synchronized circuitry that ranges in frequency from 4 to 64 Me in 160 steps-40 linearly spaced steps per octave band.

Pulses, 50 sec in duration, are transmitted over the Hawaii-

Massachusetts path, and the received pulses (differentially delayed in time as a result of the different modes of propagation) are recorded on film using the following technique. An oscilloscope is intensity modulated with the detected video output of the receiver. As the transmitter and receiver step in frequency over the operating range, the display is recorded on moving film, producing a record showing time delay as a function of frequency. This presentation is referred to as an oblique-incidence ionogram. An artist's sketch of this type of record is shown in Fig. 1.

The primary characteristics that one would hope to obtain from a ray-tracing analysis for comparison with the experimental results are summerized below:

- 1. The Maximum Observed Frequency (MOF) and the Lowest Observed Frequency (LOF) for each of the modes (e.g., mode 1,2,3,...).
- 2. The differential group time delay separating each of the modes at any given frequency (e.g., f_1).

In addition, it would be desirable to obtain a profile view of the propagation path showing the rays, their ground-reflection points and the apparent path of the rays through the ionosphere. An example of this is given in Fig. 2, showing the three modes of the ionogram of Fig. 1, at a fixed frequency f_1 .

II. AVAILABLE RAY-TRACING TECHNIQUES

The problem in synthesizing an oblique-incidence ionogram by a ray-tracing approach is actually twofold:

- 1. Can the mode structure be duplicated by a ray-tracing approach if sufficient ionospheric data are available?
- 2. In the absence of this ionospheric data, could the CRPL ionospheric-propagation predictions, available three months in advance, be used in conjunction with the ray-tracing program to predict the mode structure likely to be observed?

With this problem in mind, it was decided first to find out how other researchers had solved this or similar problems. Inquiry into the available ray-tracing techniques necessitated visiting various establishments to find out the latest information; at that time, much of it was as yet unpublished. However, since then, a meeting has been held in Lindau, Germany, to discuss oblique-incidence soundings and lonospheric ray tracing.

Table 1* is a summary of ray-tracing techniques.

An alternate possibility, the use of an analog computer to solve the ray-tracing equations, has been utilized by Wong [Ref. 17]. The difficulty in using an analog computer is that the output, height vs range (as a function of frequency), gives the distribution of energy along the great circle but does not "home-in" on the receiver (a point at a fixed range).

^{*}This information is based on material that appeared in the "Report of the Lindau Meeting on Oblique Sounding of the Ionosphere," May 6-10, 1963. Meeting held at: Institut Für Ionsopharen-Physik, Max-Planck-Institut Für Acronomie, Lindau Über Northeim. Germany.

RAY-TRACING TECHNIQUES

TABLE 1.

Assumptions

	Extreme an order delay at 1s avail	Allows magneti
Assumptions	Plane earth; planc lonosphere: E no magnetic field. [Ref. 1]	Plane earth; plane ionosphere. Allows (Ref. 2)
Class	E quivalence Method	
***	£2.7 (2	

Concentric layers with no magrected, however, angle curves are based on Martyn's equivalence theorem. [Ref. 3] netic field; empirically cor-

> Overlay Methods

Concentric layers. [Ref. 4]

Same as that of slider used. [Ref. 5] Inverse slider

Parabolic layers; no magnetic field. [Ref. 5] ionesphere Concentric

simplicity, enabling one to obtain r-of-magnitude calculation of time nd distance even when no ionogram lable; useful on short paths.

Advantages

determination of effects of earth's c field.

these data are used by CRFL in their preapparent ray paths. Use of sliders in scaling the M3000 factor from verticalincidence lonograms is important since Enables use of a slider in calculating diction techniques.

Corrects for magnetic field in generating a slider for any given lonospheric profile; particularly useful in analyzing long-distance propagation paths with low angles of elevation.

Inverse slider technique enabling quick identification of the modes on an obliqueincidence lonogram and the vertical incidence ionogram, at the path midpoint, to be determined.

Reference to the published lonograms provides a simple method of ray tracing in a parabolic layer.

Profile may be accurately represented

Synthesis of ionospheric profiles with line seg-ments. [Refs. 7,8,9]

Approximately constant magmetic field: can use any profile as above [Ref. 10]

Advantages

A general expression is developed enabling direct calculation of the ray-path length using a simple ray treatment.

By assuming concentric ionosphere for each hop but calculating each layer as it is first encountered, one can include first-order effects of a horizontal gradient in electron density, homing in on the receiver is provided, allowing rapid calculation to identify modes of propagation and to predict MUF's and ray paths from the CRPI. predictions Farabolic layers: no magnetic field; constant ratio for Ymho other layers; for X > 70° otherwise; for E = g(cos Wy) (Refs. 11,12)

Inclusion of tilts by correction of \emptyset at entry into and exit from the layers may give a refinement to the method described above.

The ray path can be approached more realistically, thus providing more accurate ray paths in the regions of extreme tilts or gradients along the great circle.

Gives a first-order approximation to supermodes and off-great-circle-path propagation. Nomograms are available for some heights and distances: others can be calculated and plotted by use of a 7090 computer.

Most thorough analysis when lonospheric can be specified in great detail; has howing-in feature incorporated.

State as soo. Iotosphere

Same as above [Ref. 1]

Isolonic Hazelgrove equations contours [Ref. 14]

intee Illting mirror reflector dimensional in the icnosphere: Martyn's equivalence theorem [Ref. 15]

Hazelgrove equations [Ref. 16]

• 5 -

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The "nome-in" capability afforded by a digital-computer program is an attractive feature. Sorting by modes and range discrimination greatly simplifies the handling of the enormous amounts of data that are calculated by the computer. One is thus able to concentrate on the path in question, having already sorted out the rays that never reach the receiver.

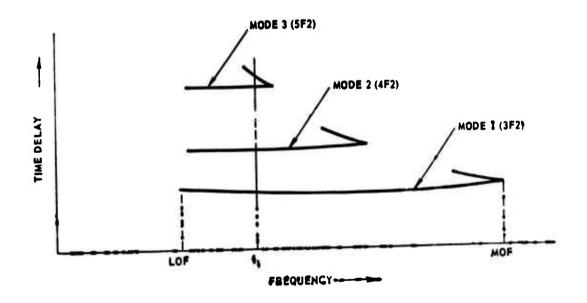


FIG. 1. THEORETICAL VERSION OF AN OBLIQUE-INCIDENCE, SWEEP-PREQUENCY IONOGRAM.

III. CHOICE OF THE KIFT-FOOKS TECHNIQUE

To synthesize an oblique-incidence ionogram (Fig. 1). it is necessary to consider only those rays that reach the receiver. Detailed knowledge of the ionosphere is not always available and, where predictions are concerned, a detailed ray-tracing approach is not justified. In fact, most of the time, only a bare minimum of data exists concerning the true electron-density profile along any given path. Even with electron-density distributions, assumptions as to the structure of the magnetic field, the off-great-circle profiles, as well as a choice of a magneto-ionic theory, need to be made prior to the use of a complete three-dimensional analysis [Ref. 10].

With these limitations, it was believed that a program which takes into account the gross changes in the ionosphere along a path at sunrise and sunset, by the inclusion of the daytime E and F1 layers and a specularly reflecting sporadic E layer, would suffice.

The major factors governing the choice of the Kift-Fooks technique were probably the rapidity with which the program could be run on a truly high-speed digital computer (either the IBM7090 or the IBM 7094) and the fact that predictions could be made, using the CRPL ionospheric propagation-predictions in their present card format [Ref. 18], on a highly automated basis.

Thus, it was decided to use the ray-tracing technique suggested by Kift [Ref. 11] and programmed for use on the Pegasus computer by Fooks [Ref. 12]. The advantages of this program are that it assumes a set of parabolic layers for the ionospheric profile and then calculates the ray path in (or through) a parabolic layer by the Appleton-Beynon [Ref. 5] equations.

Some of the inaccuracies of this technique are pointed out by Kift at the end of his article, with reference to the work of Vickers [Ref. 19]. A report that compares the Kift-Fooks technique with a more accurate technique, developed by Croft [Ref. 20], is soon to be published as another report in this series.

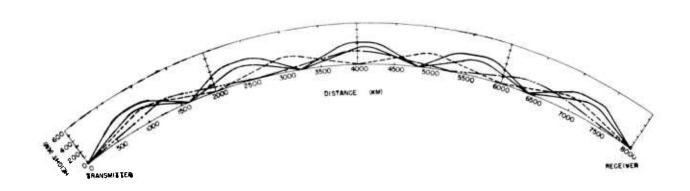


FIG. 2. CROSS SECTION OF IONOSPHERIC BAY PATHS.

IV. HOW TO UTILIZE THE KIFT-FOOKS TECHNIQUE

Before attempting to utilize the Kift-Fooks technique in the analysis of point-to-point propagation characteristics, one should know what data are available in the print-out of the program and how to use these data.

Table 2 lists the ionospheric-profile parameters along the great-circle path (from the transmitter to the receiver) in 100-km intervals. The values given are the critical frequencies of the E, F1, and F2 layers, and the height at which the maximum of the F2 layer occurs is given for the points mentioned above. Details of the exact computer output format (Tables 2,3,4) are given on pp. 11, 12, and 13.

Each ray-tracing group is identified by the transmitter latitude and longitude, the bearing to the receiver, and the time, month, and year for which the ionosphere was compiled.

An example of the present data format is given in Table 3. The description of each mode includes: names of successive reflecting layers, frequency, take-off angle, group time delay, and attenuation. The terminology used in this format is different from that recommended for use in oblique-incidence work (Appendix A). However, since this report is intended to explain the ray-tracing program in its present form, inclusion of the recommended nomenclature would have necessitated further delays.

The modes are listed in terms of increasing frequency and take-off angle (for any one frequency).

In addition, an option available to the program prints out the ground range and height of the ray for points of entry or exit of a layer and the ground-reflection points (Table 4). Thus a ray plot similar to that shown in Figure 2 could be plotted from the data of Table 4.

With knowledge of the output format in hand, one can now proceed with the discussion of how these data can be

used in the synthesis of an oblique-incidence ionogram (Fig. 1). Refferring to Table 3 and establishing the same set of coordinates as that achieved experimentally, one would then plot and join together points having the same mode description (i.e., .Fl .E .E .E). This plot could then be compared directly with the experimentally achieved data. Please note, however, that there will be an omission of the high-angle rays because of the method used in programming the computer for mode calculation and retention.

When the take-off angle and the attenuation associated with a given mode are taken into account, a first-order approximation can be made to eliminate many of the predicted modes that experience tells us just wouldn't get through.

Using vertical-incidence soundings made along or near the great circle, as a first-order correction to the CRPL prediction, enables greater accuracy to be achieved, particularly if patches of sporadic E are present which were not taken into account in the predictions. A subsequent report will be issued outlining the procedure used in this case (i.e., an after-the-fact analysis).

However, it is most important to emphasize once again the main advantage of the Kift-Fooks technique as a predictor of propagation conditions. Certainly, when detailed information regarding the ionospheric profile is available, it would make sense to utilize one of the more detailed ray-tracing programs currently available [Refs. 9,14,16,20].

By directly converting the CRPL ionospheric propagation predictions into values of $f_{\rm o}$ F2 and M3000 (the ratio of the 3000 Km MUF to the $f_{\rm o}$ F2) and subsequently using the assumption of Kift and Fooks [Refs. 11 and 12, respectively], the computer can calculate the values of height of the maximum of the F2 layer and trace all subsequent rays that reach the receiver.

Thus we have a highly automated prediction program, the details of which are specified in the following sections.

TARLE 2. IONOSPHERIC. PROFILE PARAMETERS

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TABLE 3. OBLIQUE-IONOGRAM OUTPUT DATA

ATH L	ENGTH	8045	.35 KM		TX LAT	19.5	O OFG		I' LUNG	-1.4.95		MR BEAL		5 . p. 1	
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F	• E	. 6	• f							e.00	1.44	6034.58	28.69	•10.78	163.
E	• E	. E	. €							9.00	1.54	8034.34	27.15	-11.01	129.
ŧ	. E	• E	• E							10.00	1.68	6035.43	27.12	• 7, 92	104.
F2	•F2	•F2	.62	.+2	•F2	•F2				10.00	23.19	8015.76	30.17	-29.59	
£	•E	. €	•€							11.00	1.85	8939.26	27.16	-6.69	
	.51	.51	.51	.03						11.00	13.20	7989.22	28.10	-54.13	6.
*2	.52	. F 2	2	• • • 2	.+2	. # 2				11.50	21.70	6324.14	29.87	-21-17	47.
	.12	.12	. F 2	.12	.12	. \$ 2	.12			11.00	24.17	HC41.84	30.53	-3.51	69.
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F1	•ŧ	.62	, # 2	F 2	. # 2					12.00	10.43	6021.89	29.23	-23.44	•7.
	•15				. # 2	.#2					29.90		29.60	-5.11	57.
F 2	. 72	.F2	•4.5			••2	. 5 2				23.91				51.
F 2	. # 2	. F 2	.62	.12	.F2	•• 4	•••				15.03				39.
F 2	.*2	. F 2	• • • 5	•*2						-	17.66			-13.39	• E .
12	. * 2	.F2	. 12	• • 2	.65							8042.7			43.
. F 2	.F 2	. F 2	. 12	•F2	.12	. * 2				_		6037.0			
F 2	.*2	•F2	., 5	. * 2	.6 2	. # 2	*+ 5								
5	5	., 5	• 6.5	• \$ 2							14.17				36.
	. 2	.F2	. 5 2	. 6 2	.*2							0037.7			
.F2	5	. F 2	. 12	. 12	•F2	. # 2					20.86				
• F 2		. # 2										e010.5			
.F2	. + 2	.F2	. 12	. # 2						15.6	13.7	2 0033.0	3 20.51	-11.7	31.
.F2	.52	. F 2	.12							15.0	0 17.3		6 29.1	-3.6	32
. F 2	.72	.72		2		. F 2				15.0	C 22.1	0 .045.0	7 30.1	7 -0.2	30
. F 2	. 6 2	. F 2	. + 2							16.9	: 10.0	3 0044.0	v 20.2	-9.4	5 27
.#2	F 2	. # 2	. # 2							16.0	0 13.5	2 6036.2	6 24.3	-9.6	7 24
	.12		. # 2							16.0	0 17.6	2 6947.4	8 29.3	3 2.1	3 27
	.62	. 62	•							17.0	C 6.2	9 8026.0	7 27.8	5 -14.3	3 .2
.12	- 2	.12	.+2							17.0	C 9.6	6 RE4G.6	3 28.1	7 -4.7	2 24
. F 2	.F 2	F 2								17.0	c 13.5	6 6043.7	7 28.4	.1.3	- 25
	. # 2	• 7 2	•••	• • •						16.0	0.2	6 4055.6	4 27.7	10.5	9 14
•F2											0 5.6		2 27.9	2 1.0	7 20
.F2	.12	• 1 2										9 80 42 . 5	7 28.1	7 -2.1	6 27
•F2	•F 2	• F 2	. 62									1 8040.			6 21
.F2	.F2	.F2	•F2	• F 2	•							a ab-o.5			2 19
. F 2	•FI2	. F 2										1 8042.			9 20
•F2	•F 2	• F 2	•F2									5 8033.2			
• F2	• F 2	• F 2	. f 2	, F	2							8642.			1 17
•F2	•F2	.F2													1 17
.F2	•F2	.F2	•F2									3 8042.0			3 15
. F 2	•F2	•F2										2 6044.6			
.+2	. F 2	. F 2	• F 2									2 8045			5 15
• • •										22.0	0 5.0	9 8042.	on 27.8	· 2 ·	19 14
. 12	. F 2	•F2													
	•F2	•F2								23.	00 5.	9 6037. 8 8040.	81 27.8		54 1 92 1

TABLE 4. RAY-PATH OUTPUT DATA

A OCTORES 1942 14 CHT PAMPAMEDENBO PATH TH IDMG -154.95 DFG BY NEARING 40.24 DFG		1	53. 53. 54. 54.	IA26 DEGAFES																									
. 6761	704		. 62		RANGE	377.17	460.10	\$50.15	682.74	040.20	1353.24	1599.69	1822.38	1000.1	2201.03	2638.68	2093.49	3124.21	3269.73	3547.19	3947.12	4222.24	4479.5	+621.89	4699.35	5301.74	\$655.76	5987.47	6137.61
30000	9 00 10 8	PATH LENGTH 8045.35 KH	#00E .F2	12.000 PC	ME I GHT	1+0-00	164.34	150.00	100.00	•	140.00	149.43	150.00	100.00	•	140.00	179.8	150.00	100.00	ė	140.08	174.66	150.00	100.00	•	140.00	193.95	150.00	100.00
	TR LCMG -154.95 DEG KX BEARING 50.26 DEG																												
OFUND PAT	TX LAT 19.50 DEG																												
6 DCTOBER 1962 1737,36 GMT PAHDA/BEOFUND PATM	PATH LENGTH 3045.35 KM TX LAT	3. 3. 3.		RANGE	753.05	1099.09	1920.36	2512.50	3220.44	3944.77	4635.49	5326.21	4004.97	6687.74	7365.36	8043.03													
CTOBE	Š	WOOF .F.	12-000 MC	MEZGHT	140.00	107.17	100.00		A12.74		110.63	ė	110.00	•	109.73														

415.27 4019.16 7216.02 7993.54 7744.43

204.71

HEIGHT RANGE 140*00 £70.63 150.00

437.73

517.86

335.66

630.00 875.45 1221.78 140.00 100.00 •

1630.90 1755.06 1437.13 192.09 150.00 100.00

2566.21 2349.05 2000-51 18.58 140.00 •

2887.79 2761.59 150.00 100.00

3133.23 3483.69 172.86 1.0.00 •

3869.37 3687.70 100.00 150.00

4242.68 3997.23 140.00 •

4594.63 4833.54 150.00 182.54

300.00

\$179.98 2050-00 5425.43 •

6349.59 \$778.50 6074.58

140.00 203-42 100.00 150.00 ċ

6479.62 7078.75 7382.56 7664.54 1794.74 6725.06 205.60 00.049 \$50.00 100.00

TX LAT 19.50 0EG 8 OCTOBER 1962 1737-36 GHT PAHOA/BEDFORG PATH TR LONG -154-85 DEG RX BEARING 50-26 DEG 6 OCTOBER 1962 1737-36 GHT PAHOA/BEDFORD PATH PATH LENGTH 8045.35 KM TR LAT 19.55 0EG

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. 4.2

20.904 DEGREES

MODE .F2 .F2 .F2 .F2 .F2 .F2 .F2 12.000 MC 23.913 DEGREES

TX LONG -154.95 DEG RX BEARING 50.26 DEG

.F2

293.76 HEIGHT RANGE 140.00

583.39 173.20 150.00 100.00

797.30 1264.51 1091-12 1.0.00

1458.78 1566.10 195.22 150.00

1760.07 00.001 140.00 •

2459.57 2280.54 2082.37 150.00 192.95

2568.11 100.00 6

3085.53 2782.07 1.0.00 182.28

3270.43 3435.88 3545.43 150.00 100.00

3759.33 1.0.00 •

4063.79 4253.98 4420.74 150.00 101.43

4535.11 4749.08 100.00 ė

5563.17 \$054.20 \$272.70 9472.17 00.00 193.36 150.00

6601.58 6712.95

6361.74

211.32 920.00 90.004

6102.78

00.00

\$926.92 17:15:57 7828.99 1232.82 3484° 94 1.0.00 308.56 150.00 00000 ÷

8042.95

÷

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TH LONG -154.95 DEG RK BEARING 50.26 DEG
           TR LAT 19.50 DEG
6 DC708ER 1962 1737.36 CM7 PAHDA/BEOFORD PATH
                                     9.659 DECREES
                         400E .F2 .F2 .F2 .F2
              PATH LENGTH 8045.35 KM
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                                                                                                                                               2962.70
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      ■ DCTOBER 1962 1737.36 GMT PAHDA/BEOFORG PATM
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                    PATH LENGTH 8045.35 KM
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                                                                                                                                                                                                                              7405.51
                                                                    795.34
                                                                                1164.93
                                                                                                                               3229.29
                                                                                                                                                       4001.77
                                                                                                                                                                                            5777.34
                                                                                                        1755.57
                                                                                                                                                                                                       6457.01
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                                                       HE I GHT RANGE
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                                   M00E #F2
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                                                                                                                                            169.62
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                                                                                             150000
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1565.72

TH LENG -154.95 DEG 6 OCTOBER 1962 1737,36 CMT PAMOA/BEOFORO PATH Tx LAT 19.50 DEG MODE .F2 .F2 .F2 .F2 PATH LENGTH 8045.35 - .

24 BEARING 50-26 DEC

13.565 DEGREES 17.000 MC

490-13 HEIGHT MANCE 140.00

.78.1C 101.69

1003.83 636.21 1368.75 100.00

1673.05 2179.60 12.55.21 00-041 197.43

2626.44 2991.36 3498.91 150.60

\$997.72 4171.58 4536.50 3763.34

5046.28 538C.85 5686.20 5861.9c 6726.7d 140.00 178.86 150.00 100.00 198.22 198.22 100.00 100.00 140.00 150.00

7135.07 7502.65

7678.85

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V. THE KIFT-FOOKS RAY TRACING PROGRAM

The ionospheric ray-tracing program described here is essentially the same as that described by G. F. Fooks in his report [Ref. 12]. The same equations are used and the same basic procedure is followed; however, certain modifications and additions to the program have been made to allow the calculations of reflection heights from the ionospheric layers, and to allow the calculation of an approximate value for ray attenuation due to D-layer absorption along the path.

A. PHYSICAL ASSUMPTIONS

The program uses a curved-earth, curved-ionosphere geometry, and the ionosphere is assumed to consist of a number of curved layers, each with a parabolic electron-density distribution. The ionospheric layers considered are E, F_1 and F_2 . A sporadic E layer (E_s) may also be included in the calculations; however, when it is, it is treated not as a parabolic layer, but rather as a thin, specularly reflecting sheet. The earth's magnetic field and layer tilts are ignored.

Figure 3 illustrates the geometry of the ionospheric layer structure.

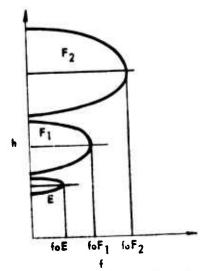


FIG. 3. IONOSPHERIC-LAYER STRUCTURE (PARABOLIC).

B. GENERATION OF THE IONOSPHERE

Figure 4 illustrates the geometric parameters for an arbitrary parabolic layer.

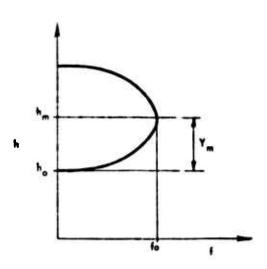


FIG. 4. GEOMETRIC PARAMETERS FOR AN ARBITRARY PARABOLIC LAYER.

Since the behavior of the E and F_1 layers is well understood, these layers are generated by several analytic expressions, which take into consideration the sunspot number and the solar zenith angle.

For the E layer we have:
$$f_{o}E = 3.4 (1.0 + 0.009) \cdot 330)^{3.2} \cdot \cos^{3.3}\chi \times 570^{\circ}$$

$$f_{o}E = 0.0 \times 570^{\circ}$$

$$h_{m}E = 120.0 \text{ km}$$

$$y_{m}E = 20.0 \text{ km},$$
(1)

where:

f = critical frequency for the layer in megacycles (vertical incidence)

SSN = sunspot number $\chi = \text{solar zenith angle}.$

For the F₁ layer:

$$f_{o}F1 = 1.4(f_{o}E)$$
 $h_{m}F_{1} = 210.0 \text{ km}$
 $y_{m}F_{1} = 60.0 \text{ km}$

(2)

For the F_2 layer, values of f_0F_2 and h_mF_2 are supplied to the program either as predicted values or observed values at arbitrary points along the path, and the program contructs a parabolic F_2 layer under the assumption:

$$y_m F_2 = 0.4 h_o F_2,$$
 (3)

where $y_m = h_m - h_o$

Values of f_0E_s , if they are different from zero, are supplied to the program in terms of their position on the path. The height of the E_s layer is assumed constant at 100.0 km.

An equation for $\cos \chi$ using the path geometry is presented in Appendix B.

In Appendix C a method is given for obtaining values of $h_{\rm m}F2$ using predicted values of $f_{\rm o}F2$ and F2 4000 MUF. These are the two parameters obtained from the CRPL ionospheric predictions.

C. EQUATIONS FOR RAY-PATH CALCULATIONS

Below the ionosphere and between ionospheric layers the ray is assumed to travel in a straight line.

The $E_{\rm S}$ layer either specularly reflects the ray or allows it to pass undeviated. For the parabolic layers the following equations apply:

$$\Delta P' = \frac{2f}{f_0} y_m \cdot \operatorname{argtanh} \left(\frac{f}{f_0} \cos i \right) \tag{4}$$

if the ray is reflected by the layer, and

$$\Delta P' = \frac{2f}{f_0} y_m \text{ argcoth } (\frac{f}{f_0} \cos 1)$$
 (5)

if the layer transmits the ray, but causes bending, where:

 $\Delta P'$ = virtual path in the layer

f = wave frequency

 f_0 = layer critical frequency

i = angle between the ray, extrapolated along a straight line to the level of maximum electron density, and the vertical at that level (as illustrated in Fig. 5).

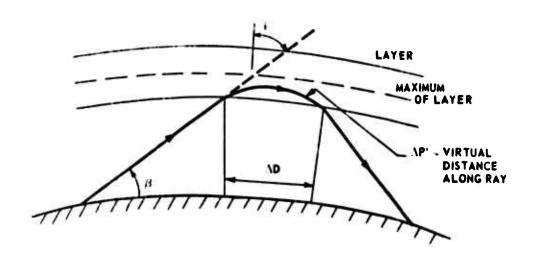


FIG. 5. OBEIQUE-INCIDENCE RAY-PATH GEOMETRY.

For transmission through a layer or for reflection from the bottom of a layer,

$$\Delta D = \frac{R}{R + h_{m}} \sin 2 \Delta P^{*}. \tag{6}$$

If the ray is reflected from the top of a layer,

$$\Delta D = \frac{R}{R - h_{m}} \sin i \Delta P^{*}, \qquad (7)$$

where ΔD is the range along the path covered while the ray is in the layer, and R is the earth's radius.

In the course of the ray tracing, as the ray enters a layer, there are three possible consequences:

- 1. The ray is reflected from the layer.
- 2. The ray is transmitted through the layer and deviated.
- 3. The ray is transmitted through the layer undeviated (straight-line transmission).

Let

$$K = (f/f_0) \cdot \cos i$$
.

Then if

$$K < 1$$
 the ray is reflected

 $K = 1 \quad P' = \infty$, the next ray is taken

 $1 < K < 2$ the ray is transmitted and deviated

 $K \ge 2$ the ray is transmitted and undeviated

 $K \ge 2$

The equations used for undeviated transmission through a layer, between layers, and from the ground to the bottom of the ionosphere are:

$$\sin i_2 = \frac{(R + h_1) \sin i_1}{(R + h_2)}$$
 (9)

$$\Delta P' = \frac{(R + h_2) \sin (i_1 - i_2)}{\sin i_1}$$
 (10)

$$\Delta D = R(i_1 - i_2) \tag{11}$$

for straight-line transmission between two points at heights h_1 and h_2 with associated vertical angles i_1 , and i_2 .

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During the course of the ray-tracing procedure, two layers may happen to overlap (most likely the Fl and F2 layers). When this occurs, the ray is extrapolated back along a straight-line path, tangential to its direction when it emerges from the first layer, to its point of entry to the second layer, (Fig. 6).

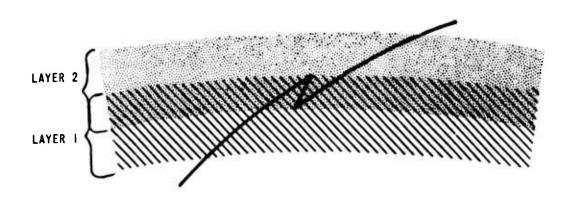


FIG. 6. OVERLAPPING-LAYER PROCEDURE

VI. STANFORD VERSION OF KIFT-FOOKS RAY-TRACING PROGRAM

A. BASIC COMPUTATIONAL PROCEDURE

Figure 7 is a logical flow diagram of the computational procedure; it is not intended as a detailed flow chart of the program, but merely as a gross logical description of the computational process.

The input data to the program are the path length between the receiver and the transmitter, the coordinates of the transmitter, the true bearing of the receiver from the transmitter, sunspot number, sun declination, apparent solar time at Greenwich; F_2 -layer data in the form of either f_0F_2 and h_mF_2 or f_0F_2 and F_2 4000 MUF: E_s data, if any, plus a range of frequencies and a range of take-off angles to be investigated for the given ionosphere, and a set of frequencies for which ray-reflection-height information is desired. F_2 and E_s data are described in terms of their range along the path from the transmitter.

Once the data for the path have been read by the program, a table of ionospheric data is produced for use by the program. Equations (1) and (2) are evaluated at 100-km intervals along the path. A second-degree polynomial is fitted to successive triplets of f_0F_2 and h_mF_2 data points and these polynomials are evaluated at 100-km intervals along the path. Tables of E_s , if required, are compiled at 10-km intervals within each E_s patch considered. When, during ray tracing, values within the ionospheric tables are required between the calculated 100-km (10-km for E_s) points, linear interpolation is used.

After the generation of the ionospheric tables, the values of the critical frequency, f and height vs range for each layer are printed out (Table 2) and the actual ray-tracing process begins.

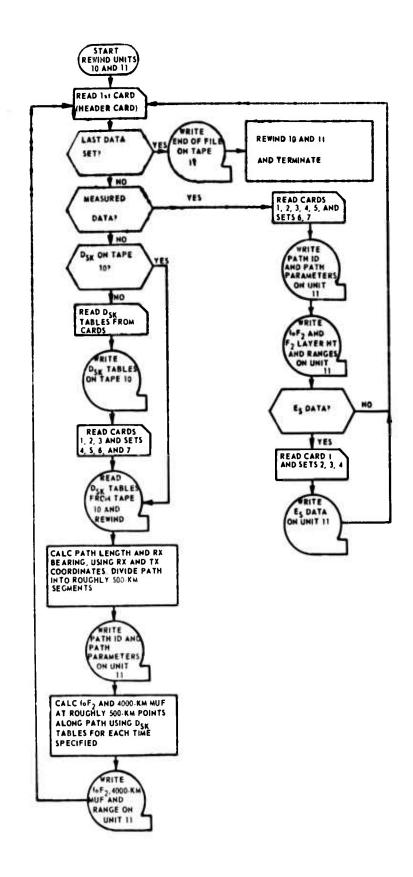


FIG. 7A DATA PROGRAM OF RAY-TRACE PROGRAM.

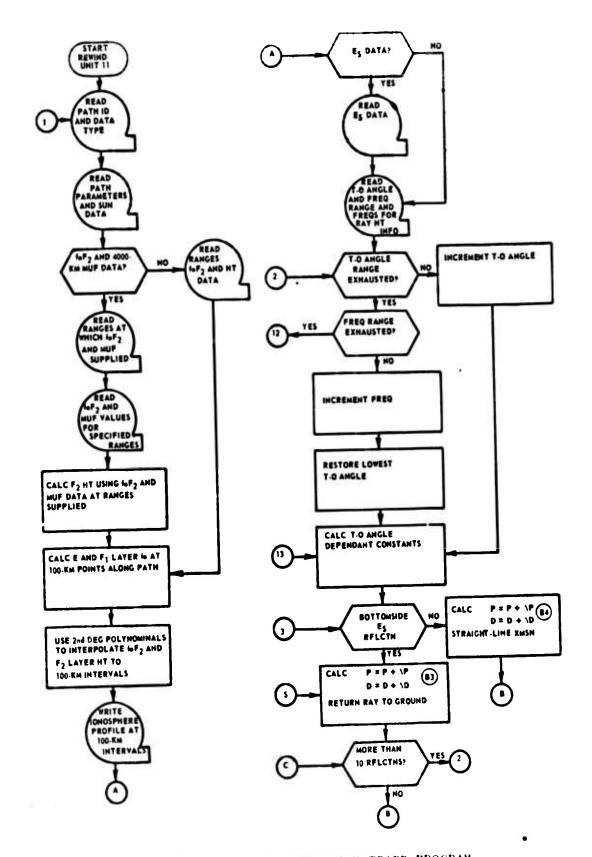
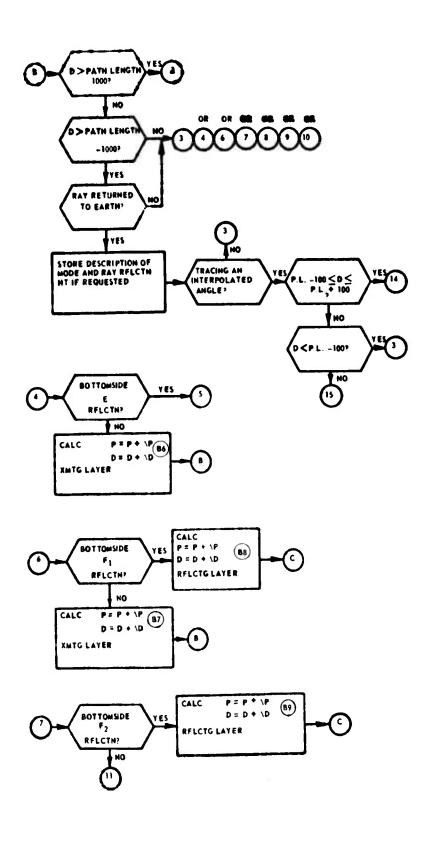
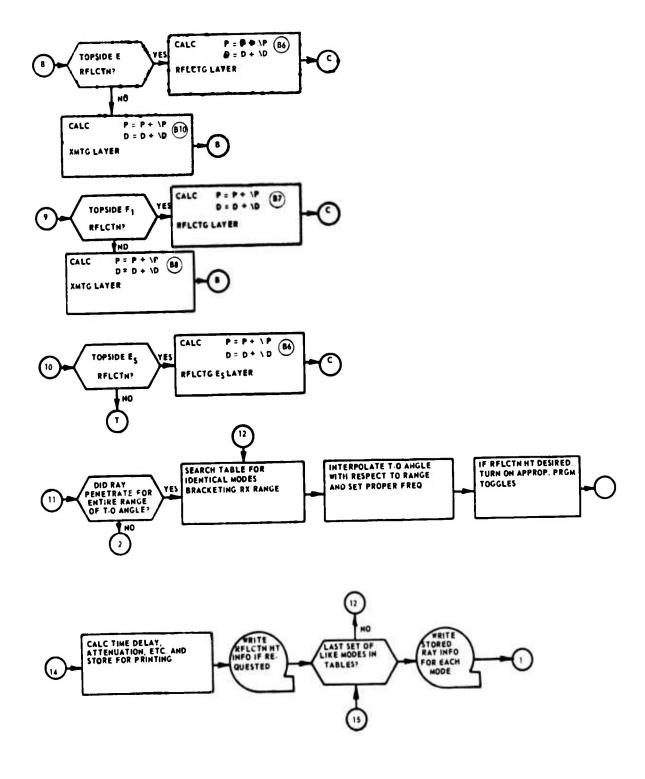


FIG. 7B FLOW DIAGRAM OF RAY-TRACE PROGRAM.





For each frequency of the specified frequency range, rays are traced from the transmitter for all take-off angles of the specified take-off angle range. A ray is traced until it falls within 1000 km of the receiver, each reflection from a layer being recorded, in coded form, in a "reflection index". A maximum of ten reflections per ray is allowed. When a ray falls beyond the receiver range +1000 km, tracing of that ray is terminated, the reflection index and accumulated values of F' and D are restored to zero and the next ray of the series is traced. When the ray falls within 1000 km of the receiver range its reflection index is stored in a table, along with P' and D for that particular ray, and the next ray of the series is traced.

Once all rays for a given frequency have been traced, the table of reflection indices is searched for rays of like modes, a linear interpolation of take-off angle with respect to the actual range of the ray and the range of the receiver is performed, and a new ray with the interpolated take-off angle is traced. At this time the height of the ray at its reflection points is calculated in addition to an estimate of D-layer attenuation. (These equations appear in Appendixes D and E, respectively.) If this new ray does not fall within ±100 km of the receiver, it is ignored and the next pair of like rays (if any) is considered. If it falls within ±100 km of the receiver, its delay time is calculated from

Delay time (ms) =
$$\frac{P' - (\text{Receiver Range - D})}{300.0}$$
 (12)

and the final results are printed. The next pair of like rays (if any) in the table is then considered.

The printed output (Table 3) for each mode consists of the path parameters, the reflections that take place for the mode in "decoded" form, the frequency, take-off angle, ground range, and delay time for the mode. A list of heights

vs range for the reflection points on the path is printed if this information is requested of the program (Table 4).

This process continues for each frequency in the specified range until the frequency range is exhausted or until some frequency in the range fails to propagate any rays between the transmitter and receiver. At this point new ionospheric and/or new path data may be read into the program and the process may be repeated.

B. PROGRAM DETAILS

The ray-tracing program is written in the FORTRAN II computer language, specifically for an IBM 7090 data-processing system. With modifications to the input/output statements, the program could probably be adapted, with little trouble, to other systems such as the IBM 709, CDC 1604, etc. The program requires two magnetic-tape units, one designated logical unit 11 and the other designated as logical 6. The tape on logical unit 11 serves as an input tape and the tape on logical unit 6 is the output tape.

Data for the ray-tracing program are prepared by a second program, which shall be referred to as the "data program". The data program requires, as its input, tables of f_0F_2 and M 3000 factor coefficients for the month for which ray tracing is to be done, in addition to parameters associated with the paths which are to be ray-traced. The output of the data program is a magnetic tape that is used as the input tape for the ray-tracing program.

The tables of f_0F_2 and M 3000 factor coefficients (Dsk) may be obtained in punched-card form from the Bureau of Standards CRPL at Boulder, Colorado. (See CRPL Ionospheric Predictions, Handbook 90. [Ref. 18]) These tables also contain the sunspot number for the month.

The data program will also accept as input, actual measured values of f_0F_2 and F_2 -layer real height as a function of their position on the path, to be used by the ray-tracing program.

Appendix F contains listings of the FORTRAN source programs for both the data and ray-tracing programs in addition to sample output from the ray-tracing program which has already appeared as Tables 2,3, and 4, and sample input for the data program.

C. OPTIONS AVAILABLE ON THE DATA PROGRAM

In preparing data for paths to be ray traced for a given month, the tables (on cards) of D_{sk} need be read only once by the program. When the program reads the D_{sk} tables from cards it places them on magnetic tape (logical unit 10), in binary form, where they are available for future use.

Normally, ray tracing is done over a given path, for a 24-hour period, once each hour: however, provisions have been made in the data program to allow tracing for an arbitrary number of selected times (at most 100) on any given path. The number of times to be traced is specified to the program, followed by the actual times to be used. For example, in the normal case 24 times would be specified followed by each hour from 0 through 23.

When empirical data are to be used for ray tracing a given path, that is, ionosonde records of f_0F_2 —and F_2 —layer real heights, even though the CRPL tables of D_{sk} are not used, the D_{sk} tape must be mounted on unit 10 none—theless. These empirical data are presented to the data program in the form of f_0F_2 —and F_2 —layer height as a function of distance along the great-circle path, measured in kilometers from the transmitter. There must be an odd number of measurement points specified.

Sporadic-E data may also be included when the empirical data form is used. No provisions have been made to include sporadic-E when the prediction tables are used. However, this omission may be remedied with only minor difficulty: and procedure will be discussed after a description of the output from the ray-tracing program.

The data program writes a BCD tape on unit 11 which is used as an input tape by the ray-tracing program.

D. INPUT TO AND OUTPUT FROM THE RAY-TRACING PROGRAM

Input to the ray-tracing program is provided by a binary-coded decimal (BCD) tape written by the data program. It is to be mounted on unit 11. Output from the ray-tracing program consists of an ionospheric profile (Table 2), constructed from either the CRPL predictions or empirical data, at 100-km intervals along the path; path identification information such as the name or number of the path, the time, month and day for which the tracing is being done, etc. The actual path-identification information used is up to the user and will be explained in the section on the preparation of input cards for the data program.

The length of the great-circle path between the transmitter and receiver, the latitude and longitude of the transmitter (Tx), the bearing from the transmitter to the receiver are all printed and labeled for each time a series of rays is traced. (In the normal case, once each hour for the 24-hour period.)

Actual information concerning the rays traced appears in Table 3 under the following column headings, with the associated definitions:

MODE: The mode structure of the ray propagated between the transmitter and receiver. The symbol "E" indicates a ray reflection from the bottom side of the E layer. The symbol "E" indicates a ray

reflection from the top side of the E layer. The same definitions apply to E_s F_l , and F_2 layers. Obviously, "- F_2 " is not defined and will not occur.

FREQ: The frequency (in megacycles) of the ray traced.

BETA: The take-off angle (in degrees) of the ray traced.

DIST: The actual ground distance (in kilometers) the ray travels between transmitter and receiver. Because of inaccuracies in the ray-tracing technique this distance will, in general, not be equal to the actual path length.

TIME: The delay time (in milliseconds) of the ray traced, corrected to the actual path length.

DIFF: The difference (in kilometers) between the ground distance the ray travels and the actual path length.

DB: The attenuation, (in decibels) the ray experiences due to D layer absorption only.

Information concerning reflection heights of the rays is also printed (Table 4), but only if it is specifically requested of the program. The details for obtaining this information are discussed in the next section.

If the reflection-height information is requested it appears in the following form: the path parameters and identification are printed, the MODE is specified (as above), along with the ray frequency and take-off angle. The heights appear under a column headed HEIGHT and the corresponding range appears under a column headed RANGE; both are in kilometers.

In all cases an ionospheric profile along the path is printed prior to the printing of any other information. It consists of the path-identification information and columns headed FOE, FOF1, FOF2, HT FOF2 and RANGE. The $f_{\rm O}$ values are in megacycles and the $f_{\rm O}F_{\rm C}$ height column is in kilometers, as are the ranges. The range is measured from the transmitter end of the path, and the values fall on the great circle between the transmitter and receiver. The path parameters printed consist of the PATH LENGTH, TX LAT (transmitter latitude), TX LONG (transmitter longitude),

and RX BEARING (the great-circle bearing from the transmitter to the receiver).

In order to provide sporadic-E information on ray tracings that make use of the CRPL prediction tables, it is necessary, first, to accomplish the required tracings without E_s data, and then, using the f_0F_2 - and F_2 -layer real-height information provided by the ray-tracing program, resubmit this information to the data program in the empirical-data format, along with the required E_s data. This technique was adopted in the interest of programming simplicity and, since the inclusion of E_s is usually done on an "after-the-fact" basis, it would seem a justifiable approach.

E. INPUT-CARD FORMATS FOR THE DATA PROGRAM

1. First Card

The first card of every data set contains the program variables called IDATA, IDSKC, IEND, in that order. This card is read under a FORTRAN format of (312). The value of each of these variables may be "1" or "0" (zero).

If IDATA = 1: Data are to be supplied to the program in the empirical format.

If IDATA = 0: Data are to be supplied to the program in the form to make use of the CRPL ${\tt D}_{sk}$ tables.

If IDSKC = 1: The D_{sk} tables for the month in question have not yet been put on magnetic tape and immediately follow this first card.

If IDSKC = 0: The D tables for the month in question are on magnetic-tape unit 10.

If IEND = 1: An END OF FILE mark is to be written immediately on magnetic-tape unit 11 and program execution is to be terminated.

If IEND - Q: Additional sets of path data follow.

2. Cards for Program Using Dsk Tables

The following cards constitute the information required to generate data for the ray-tracing program using the D_{sk} tables:

Card #1: Contains the program variables.TXLAT, TXLON,

RXLAT, RXLON, SUNDEC.

TXLAT: The latitude of the transmitting point in degrees and hundredths of degrees. North latitude is +; South latitude is -. Format F7.2.

TXLON: The longitude of the transmitting point in degrees and hundredths of degrees. East longitude is +; West longitude is -. Format F8.2.

RXLAT: The latitude of the receiving point. Same as TXLAT.

RXLON: The longitude of the receiving point. Same as TXLON.

SUNDEC: The declination of the sun in degrees, Format F7.2.

This information is obtained from the Nautical Almanac.

Card #2: Contains the program variables FREQL, FREQD, FREQH, ANGLL, ANGLD, ANGLH.

FREQL: The lowest frequency to be traced, in megacycles. Format F7.3.

FREQD: The frequency increment to be used between the lowest frequency and highest frequency, in megacycles. Format F7.3.

FREQH: The highest frequency to be traced, in megacycles. Format F7.3.

ANGLL: The lowest take-off angle to be traced, in degrees. Format F7.3.

ANGLD: The take-off angle increment to be used between the lowest angle and highest angle, in degrees, Format F7.3.

ANGLH: The highest take-off angle to be traced, in degrees. Format F7.3

Card #3: Contains the program variables NTIMES.

NTIMES: The number of specific times of day to be used by the ray-tracing program for the path described.

O < NTIMES ≤ 100. Format I3.

Card Set #4: Contains the program variable TIME (I). One card for each value of TIME (), in GMT, to be used. The number of cards must correspond to NTIMES. Format F6.2.

Card #5: Contains the program variable NCHT is

the number of discrete frequencies for which detailed ray-reflection-height information is desired. If no such information is desired, NCHT = 0. Format I 4. $0 \le NCHT \le 50$.

Card Set #6: Contains the program variable HFREQ (I), $I=1,2,\ldots$ NCHT. There are NCHT cards in this set, each containing a discrete frequency for which ray-reflection-height-information is required. If NCHT = 0 there are no cards in this set. Note - frequencies specified must correspond to frequencies specified to be traced by the program. Format F7.3.

Card Set #7: Contains alpha-numeric data in columns l thru 60 for identification purposes. One card must appear for each time used. The actual information used is at the user's discretion.

Additional sets of path data may follow, providing each set is prefaced by a card as described in Sec. 1.

A card of the type described in Sec. 1 with IEND = 1 should immediately follow the last set of path data.

3. Cards for Program Using Real-Height Measurements

The following cards constitute the information required to generate data for the ray-tracing program using actual measurements of f_0F_2 - and F_2 -layer real height. Remember, it is necessary to have the D $_{\rm sk}$ tape mounted on unit 10, even though the D $_{\rm sk}$ tables are not used!

A card as described in Sec. 1 with IDATA = 1.

Card #1: Same as card #1, Sec. 1.

Card #2: Same as card #2, Sec. 1.

Card #3: Contains the program variable NSETS. NSETS:

The number of sets of empirical data, for the path described by cards #1 and #2, to be read. 0 < NSETS. Format I3.

Card #4: Same as Card #7 of Sec. 1.

Card #5: Contains the program variables NPTS, SSN, HOUR.

NPTS: The number of measurements along the path as described by cards #1 and #2.

 $3 \le NPTS \le 100$ and must be odd. Format 13.

SSN: Sunspot number. Format F5.1.

HOUR: The time, in GMT, of the measurements. Format F6.2.

Card Set #6: Contains the program variables AFOF2(I),

AHT(I), DIST(I). I = 1, 2, . . . NPTS.

AFOF2(I): f_0F_2 in megacycles at the point I. Format

AHT(I): Real height of the F₂ layer maximum at the

point I, in kilometers. Format F7.2.

DIST(I): The distance from the transmitter along the great-circle path to the point I, in kilometers. The first measurement must be at the transmitter (DIST (1) = 0) and the last measurement must be at the receiver (DIST (NPTS) = path length). Format F9.2.

Card #7: Contains the program variable IES. If IES = 0, no $E_{\rm S}$ data are to be considered. If IES = 1, $E_{\rm S}$ data immediately follow. Format I 3.

4. Cards for Program Using Sporadic E Data

Card #1: Contains the program variable NPATCH.

NPATCH: The number of sporadic E patches on the path this particular time. O < NPATCH < 10. Format I4.

Card Set #2: Contains the program variables PSTART(I), PEND(I), I = 1, 2, ... NPATCH.

PSTART(I): The distance from the transmitter, along the great-circle path, of the starting point of E_s patch number I.

PEND (I): The distance from the transmitter, along the great-circle path, of the ending point of E_s patch number I. Format 1X, 2F9.2.

Card #3: Contains the program variable NPT. The number of $f_{o}E_{s}$ values to be read in for patch number "I". $0 < NPT \le 10$. Format I 4.

Card Set #4: Contains the program variables ESDIST (I,J),

TFOES (I,J) I = 1, 2...NPATCH, J = 1, 2,...NPT.

ESDIST (I,J): The distance from the transmitter along the great-circle path to the point (I,J). Note that ESDIST (I,1) must=PSTART(I) and ESDIST(I,NPT) must = PEND (I).

TFOES(I,J): f_0E_s at the point (I,J). Format 1X, 2F9.2.

F. DATA-SET EXAMPLES

Three sets of examples are included at the end of this report to illustrate graphically the preparation of data sets in the form described above in Sec. E.

G. PROGRAMS

Card decks of the FORTRAN source programs for both the data and ray-tracing programs are available from the Stanford Radioscience Laboratory.

H. RUNNING THE PROGRAMS

To run the data program, prepare the appropriate data-input deck in the appropriate format, and submit this with the 7090 binary deck for the data program, along with the appropriate control cards for the FORTRAN MONITOR in use. (This varies with the 7090 installation.) Specify the tapes to be mounted on logical units 10 and 11. Naturally, if D_{sk} tables are to be read from tape, a specific tape must be mounted on unit 10. At the end of the run, unit 11 will contain the input data to be used by the ray-tracing program.

To run the ray-tracing program, mount the appropriate data tape on logical unit 11. Submit the 7090 binary deck for the ray-tracing program along with the appropriate FORTRAN MONITOR control cards. Output from this program appears on the "normal" FORTRAN output tape unit 6.

Neither program makes use of any sense switches or other console features.

VII. CONCLUSIONS

In describing the reasons why the Kift-Fooks technique was chosen, how it would be used in the analysis of propagation data, and giving details of the program for use on a high-speed digital computer, no comparisons were made with actual records taken. It remained the intention of the authors to outline the work done here at Stanford and their reasons for doing it.

Comparison of ray tracings with experimental data has been done on several paths and the results of these comparisons are scheduled for another report.

Hopefully, the reader of this report will find sufficient information to enable him to reproduce this version of the ray-tracing program for use on available computers should he desire to do so. Duplicate decks of the program can be obtained from the authors by written request.

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APPENDIX A. TERMINOLOGY

This Appendix has been taken directly from the "Report of the Lindau Meeting on Oblique Sounding of the Ionosphere," May 6-10, 1963. The recommendations listed below are to be submitted to URSI and are also scheduled to be published in the IQSY notes.

It was recognized that, for purposes of data interchange, a need exists for the standardization of certain terms. As a first step in this direction, the following recommendations are made.

- Capital letters should be used in oblique-incidence work in contrast to the small letters agreed upon in vertical-incidence work.
- In view of the ambiguity in the meaning of << usable >>,
 the term maximum usable frequency (MUF) should be
 eliminated in the description of oblique-incidence
 ionograms.
- 3. The use of the word "virtual path" should refer to the time of flight (group delay) in oblique propagation work.
- 4. In ray tracing the following symbols are suggested (Fig. Al).
 - a. \emptyset the angle of incidence at the bottom of the ionosphere.
 - b. Ør the angle of incidence, at the real height of reflection, of the extension of the linear ray path below the ionosphere.
 - c. i the angle between the ray path and the vertical at any point along the path.
 - d. \triangle the angle of elevation at the ground.

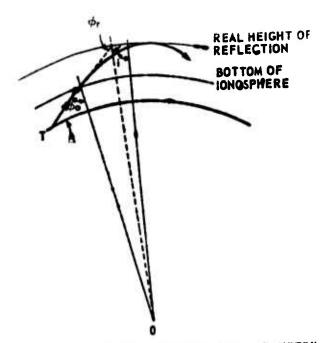


FIG. A1 RECOMMENDED RAY-PATH GEOMETRY.

The following terminology is suggested for the description of path structure (Fig. A2).

5. For propagation paths involving reflections by different layers, the reflections (or hops) should be specified in order of their position with respect to the transmitter. Thus 5E - 3F2 indicates five reflections from the E layer near the transmitter followed by three reflections from the F2 layer (Fig. A2-a).

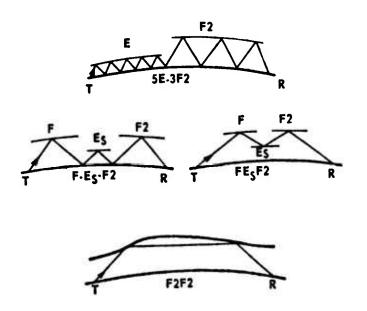


FIG. A2 RECOMMENDED MODE IDENTIFICATION.

6. The use of a dash is convenient for the representation of a ground reflection. The absence of a dash will then show up M-type ray paths and "supermodes." example F - E_s - F2 (Fig. A2-b) represents an F-layer hop followed by ground reflection to the lower side of the E_s layer, reflection back to ground, then reflection to the lower side of the F2 layer and finally back to ground. On the other hand F E_s F2 (Fig. A2-c) represents an M-type path in which the ray is reflected from the F layer to the upper side of the E_s layer, back up to the lower side of the F2 layer and down to the ground. The symbol F2F2 (Fig. A2-d) means an F2 reflection followed by another F2 reflection without an intermediate ground reflection (supermode).

The following terms are suggested for the description of oblique ionograms (Fig. 13).

- 7. MOF (Maximum Observed Frequency) means the highest frequency on which the sounder-transmitter signals are observed on the ionogram, regardless of the propagation path involved.
- 8. LOF (Lowest Observed Frequency) means the lowest frequency on which the sounder-transmitter signals are observed on the ionogram, regardless of the propagation path involved.
- 9. These terms (MOF and LOF) may be used also to describe identifiable modes. For example 2F2 LOF means the lowest frequency (observed on the ionogram) which is propagated by two reflections at the F2 layer and an intermediate ground reflection. The 2F2 MOF means the highest observed frequency associated with two-hop F2 propagation, regardless of whether the signal is propagated by refraction, by scatter, or by a combination of both mechanisms.
- 10. The lowest observed frequency of the high-angle ray may be distinguished from that of the low-angle ray by the letters H and L respectively. Thus 2F2 HLOF is the lowest frequency (observed on the ionogram) of the signal that is propagated via the high-angle, two-hop, F2 path and 2F2 LLOF is the lowest frequency (observed on the ionogram) of the signal that is propagated by the low-angle, two-hop, F2 path.

- 11. The one-hop modes do not need the number 1(one) in front. For example, F2 LLOF means the low-angle ray LOF for the one-hop, F2 ray path.
- 12. When it is required to distinquish between the ordinary and extraordinary ray paths an "o" or "x" may follow in parentheses. The F2 MOF(x) is the maximum observed frequency of the extraordinary wave that is reflected once at the F2 layer.
- 13. Often the MOF for an identifiable path is greater than the frequency on which the regularly refracted components of the high-and low-angle rays join. It is suggested that the latter frequency be called the "junction frequency" and that it be denoted by JF.

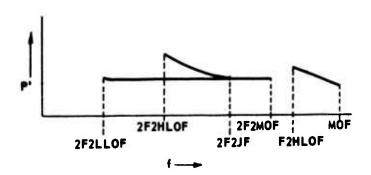


FIG. A3 RECOMMENDED IONOGRAM-SCALING PARAMETERS.

APPENDIX B. CALCULATION OF THE SUN \circ S ZENITH ANGLE, χ

$$\cos \chi = \sin \lambda_1 \sin \lambda_2 + \cos \lambda_1 \cos \lambda_2 \cos \left(\theta_2 - \theta_1\right)$$

$$\sin \lambda_1 = \sin \lambda_0 \cos \left(\frac{d}{R}\right) + \cos \lambda_0 \sin \left(\frac{d}{R}\right) \cos \alpha$$

$$\cot \left(\theta_1 - \theta_0\right) = \left[\sin \lambda_0 \cos \alpha - \cos \lambda_0 \cot \left(\frac{d}{R}\right)\right] \sin \alpha$$

$$\theta_2 = \left[\frac{(T-12)}{24}\right]. 2\pi \text{ (neglecting equation of time)} \quad (B.1)$$

where

 λ_0 = latitude of transmitter

 θ_0 = longitude of transmitter

T = time in hours (U.T.)

 λ_{o} = declination of sun

 α = bearing E. of N. of receiver from transmitter

 θ_0 = longitude of sun

 λ_{γ} = latitude of point on path

 θ_1 = longitude of point on path

d = distance from transmitter to point on path

R = radius of earth

The data program computes α and the path length, using the latitude and longitude of both the transmitting and receiving points and supplies the ray-tracing program with these parameters, in addition to the latitude and longitude of the transmitter. The data program also supplies a set of distances d_i at roughly every 500 km along the path at which f_0F2 and F2 4000 MUF are supplied by the data program.

APPENDIX C. A METHOD FOR COMPUTING F2 LAYER HEIGHT $h_{\rm m}$ FROM VALUES OF $f_{\rm o}F_{\rm 2}$ AND F2 4000 MUF

A nomogram of height h_m versus the ratio of F2 4000 MUF and f_0 F2 for a parabolic layer with $Y_m = 0.4 h_0$ is presented in the Fooks report [Ref. 12]. A polynomial expression, valid for

$$2.15 \le \frac{\text{F2 4000 MUF}}{f_0 \text{F2}} \le 4.09,$$
 (C.1)

which approximates the nomogram with maximum error in \mathbf{h}_{m} of \pm 6 km, is used in the program to compute $\mathbf{h}_{\mathrm{m}}.$

Let
$$x = \frac{F2 + 4000 \text{ MUF}}{f_0 F2} = 1.1 \text{ (M3000)},$$

$$h_{m} = \left(\frac{2218.59}{x^{1.7083}}\right) + 19.44 (4.09 - x) (x - 2.15) + 46.0 (3.0 - x) (4.09 - x) (x - 2.15)$$

APPENDIX D. CALCULATION OF REFLECTION HEIGHTS OF THE RAY IN A LAYER

The height of reflection $h_{\mathbf{r}}$ is calculated as follows:

$$h_{r} = h_{o} + Y_{m} \left[1 - \sqrt{1 - \left(\frac{f}{f_{o}} \cos i \right)^{2}} \right]$$
 (D.1)

in the case of a ray reflecting from the bottom of a layer, and

$$h_{r} = h_{o} + 2Y_{m} - Y_{m} \left[1 - \sqrt{1 - \left(\frac{f}{f_{o}} \cos i \right)^{2}} \right]$$
 (D.2)

in the case of a ray reflecting from the top of a layer.

The definition of the parameters is the same as in

Eqs. (4) and (5).

APPENDIX E. CALCULATION OF RAY ATTENUATION DUE TO D-LAYER ABSORPTION

The following expression, taken from RPU No. 9 [Ref. 21] is an estimate of the absorption in the D layer

$$DB = \frac{615.5 (1.0 + 0.0037 \cdot SSN) \cdot \cos^{1.3} (0.881\chi) \cdot N \cdot \sec \phi_{D}}{(f + f_{h})^{1.98}}$$
(E.1)

where

SSN = sunspot number

 $\chi = sun's zenith angle$

N = number of ray passages through the D layer

f = ray frequency

 ϕ_D = vertical angle which ray makes with the D layer

f_h = gyro-frequency

DB = number of decibels of ray attenuation

In the ray-tracing program the D layer is assumed to be at a height of 70 km. This height plus ray take-off angle allows the calculation of ϕ_D . Since the program assumes a constant ray take-off angle, this quantity ϕ_D is computed only once for each mode. An average value of $\cos \chi$ is used for each mode and an average value of f_h along the path is used in the calculation.

APPENDIX F. LISTING OF DATA AND RAY-TRACING PROGRAMS, SAMPLE OUTPUT AND INPUT FORMATS

The following figures consist of sample input data for the data program, a listing of the data program, a listing of the ray-trace program, and sample output from the raytrace program.

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PI R Z Z	60 TO 11	8 IFFPLKM-\$5800.09 9.9.10	9 N=28	60 10 91	10 N=31	A1 FINC=PLKM/FLOATFIN-11	PD157111=7.0	PLATIT: #TXLATR	FFETXEONRY 12-19-13	12 PLON(1)=TXLONR+TWOP!	GD 70 14	13 PLONI11 TXLONR	14 TXLONM=-TXLONR	SINLAT#SINFGTXLATRP	COSLAT=COSF (TWLATR)	SENAZMESINF (AZMTH)	COSAZM#EOSF(AZMTM)	DO 24 1@2.N	D=FLOBT#(1-1)*FINC	SINO=SIMF(O/R)	COSD=COSF(0/R)	SINL1=SINLAT+COSO+COSLAT+SINO+COSAZ*	ARG1=SERTFIE-0-SINLI*SINLI	ARG2=SENL1/ARG1	FLAT1=#TANF (ARG2)	COT=(SINLAT*COSAZM-COSLAT*CESO/SIND)/SINAZ#	ATANG#ATANF(1.0/COT)	IF(AZMTH-PI) 15.18.18	15 IF(ATANGF A6-17-17	16 THI=THLONM+ATANG	

TANG-911		20.19	ANG		(TANG+PI)		3.23					
17 THI-TXLONM+LATANG-PIP	60 10 21	18 IF(ATANE) 20.20.19	19 THI-TXLCHM+ATANG	60 10 21	20 THISTXLONM+(ATANG+PI)	21 THI=-THI	(FITH) 22.23.23	72 THI-THI-TWOPE	23 PDISTITIOD	PLATII1+FLATI	24 PLONIII .* HI	WE TURN

DATA PREPARATION PROGRAM FOR MAY TRACE TRUCKS		
DIMENSION CFO=2160.251.CMUF3160.251.PDIST11001.PLAT11001.PLDM11D01	2	READ INFUT TAPE S.B.NS.NK. CMUFSW
DIMENSION WMPATH(10).A(20).B(20).GF(25.60).GM(25.60).TIME(100)	6	NKP1.04x.41
DIMENSION AFOFZ(\$00). AMT(1961.515T(1961.HFREG(50)	•	45P1+N+1
DIMENSION PSTART(201.PEND(101.ESOIST(10.101.TFOES(10.10)	6	CMUF3(NKPI .NSPI) . CMUF3V
DEGRAD=(3.1415927/180.00	•	WRITE TAPE 10.((CMUF3(1.J)eJ=1.NS1)elmleNK1)
RADOEGe1180.073e1489927e	•	ENO FILE 1D
I REWIND TO	•	REWING 10
REVIED 11	•	60 10 11
2 READ INPUT TAPE 9-9-10ATA-10SKC-1END	10	10 READ TAPE 10.NF.NMF.WIF.NIIF.SSN
3 FDRWAT#9128	11	MK]=MF+]
JF(FEND-18 301035,309	12	NS1=20NHF+1
401 1F81DATA-18 493668	13	READ TAPE IN. ((CFOF2(1.J).Jel.NS1).I=1.NK1)
	14	MILES HERE BOSHES HIN MILES HINE
READ INFUT TAPE 4.60NFONFONIFONIFOSSN.NS.NK.CFOF2(1.1)	2	WK]:WW+]
FORMATI21X-\$2-2X-12-68-\$2-2X-12-9X-F5-01-3X-12-3X-12-3X+E14-71	16	NS1 = 2 = NHM + 1
WRITE PAPE 10. NF . NIF . NIFF . SSN	11	READ TAPE 10.((CWUF9f1.J).J=1.PF511.1=1.NK1)
MFDSK=#(WF+1)#(2#WHF#1)-8	138	REWIND 10
NK1=4F+1	11 91	11 READ IMPUT TAPE 5.12.TXLAT.TXLON.RXLAT.RXLON.SUMDE
451=294HF+1	20 17	12 FORMAT(2(F7.2.F8.2).F7.2)
50 7 F±1.WFD5K	21	READ INFUT TAPE 5.12-1.FREQL.FREQD.FREQH.ANGLL.ANGLD.ANGLH
READ PUPUT TAPE 5.88.MS.NK.CFDF2V	1221	1901 FORMATIGET.
MKP1=NK+1	23	MEAD INPUT TAPE 5-19-WITHES
NSP1=NS+1	24	19 FORMATE19)
CFOF2(WKP1+WSP1)=CFOF2V	\$\$	DO 1301 PeloNTIMES
FORMAT(54x+12+3x+12+3x+14+7)	26 145	1451 READ 14PUT TAPE 5-1972-11ME481
WRITE TAPE IN-(ICFOF211-JI+Jah-NSI1-1=1-MK1)	27 10.	14-2 FORWATIF6.21
READ INPUT TAPE 5.6.NM.NMM.NIM.NIIM.SSN.NS.NM.CML.F311.11	2	READ THRUT TARE S.1309.4CMT
WALTE TOPPE 10. NW. NAME. NIM. NITE	561 62	1903 FORMATCIA1
NADSK=1 (NM+1) 0 (20 NH+4) 1)-1	2	FINCETT 1907-1907-1906
4K1=NM+1	31 130	1964 DO 1909 1+1-MemT

	C24 = C05 F (2 - 0 = 4)
2307 CALL LATLONITKLAT . TKLON . RKLAT . RKLON . PLENGT . AZMTM . PDIST . PLAT . PLON . 66	DO 16 KA-1-LIF
45	IS GFII-KAI-GRAISX-SV-52V-CH-CV-C2V-KA-KF-LF-LIFF
TXI ONH == TXLON	DO 17 KA-1-1M
RXBER=RADDEG*AZMTH	17 GMII-KAIPGKAISTH-STV-CH-CY-CZV-KA-KM-LM-1M)
READ IMPUT TAPE 5.14.NMPATH	18 CONTINUE
71 FORMATIIOA6)	19 00 31 I=f-NPTS
72 HOUR=TIME(1)	GMT=15.0-HOUR-180.0
73	T-GHT+RADEG+PLONII!
1495*1	1F(T-180.01 21-21-20
94 18H=0	20 T=T-360.0
WRITE OUTPUT TAPE 11.15.NMPATH.ITVPE.PLENGT.TRLAT.TRLONM.CANBER. 76	60 10 23
15SN.SUNDEC. HOUR. NPTS. IFH. (POISTII) - I = I - NPTS!	21 [FIT+180.n] 22.23.23
15 FORMAT (1046-15/1X-F3-2-1X-F6-2-1X-F7-2-11-F6-2/1X-F9-1-74-F6-2-1X-	22 TeT+360.C
1F9.2/1X.13.12/(1X.F8.2))	23 TREDEGRADET
11YPE=0	A0.0.0
01 KF=NIF+1	DO 24 KAFIOLIF
LF=N11F+1	26 AO-AO-CFOFZIKA-11-GFII-KA1
LIF=NF+1	FOF2=A0
KH=N1N+1	00 26 Je26LMF
00 [M=R]][M+]	A(J)=0+0
IN=NM+1	0.01.0.0
07 [HF=NHF+]	J\$Ae20J-1
L HM=NHM+1	2-6-9-956
00 18 1=1.NPTS	DO 29 KA-1-LIF
90 #=PLAT(1)	G-GF (1, FFA)
e-PLON(1)	At Jimat Ji + CFOF 21KA + JSAI + G
	29 BtJ:=RtJ:=CFOF2tKA=J5B:=G
SA-SINF(V)	FUMIOFLOATFIJAII
\$2V#SINF(2m0eV)	26 FOF 2-FOF 2-(At JI OCOSFIF JM 10 TRI+Bt JI OS INF (FJM 10 TRI)
66 CH=COSF(H)	A0*0.0
*	

	120 00 00 10	161
PO BOURDS SERVOIT SERV	190 95 PND PILE 19	163
P#30000#0	133 PEUINO 13	164
₽0 29 Je2eL**		165
A(1)=000	*	991
0.0=(1)0	1	1.67
1+0 00= 486	135 PERS TURIT TEPE SOTSOSONOM	168
JSB#20J02		9
80 20 KA=101"	137 3601 00 9697 1-10-NF-17	176
GeGW Tex A B	136 9602 PEAN INPUT TAPE 5013060MFFEGES	171
A(4) = A(4) ocaup3 (RAoJSA) os	6016	172
28 8(3)=8€J)+C@UF3(KA+JSR**6	TABLE CALL LATLONITALATORALATOR ALDNODLENGTOAZHTH. PDISTORALATORATORALATORATORALATORATORALATORALATORALATORALATORATORATORATORATORATORATORATORATORATOR	173
PUMI=FEGAFF (Joh)	Sheet the	174
CARLONG CONTROL CONTROL CONTROL CONTROL CONTROL CONTROL CARLON CON		176
##1600=1-1-###0000####	1	
MRIVE CUTPUT TAPE SEGNOFOFZAPTHYORG	sale and their the Sessonsers	0
og pokeatera potatofold		170
sy continue		170
0.83	1	180
BRITE OUTPUT TAPE 18-92-8159-546000-54600-546000-55600-546000-556000-556000-556000-556000-556000-556000-556000-556000-556000-556000-5	141	181
49 FORPATIES /3FTe3/9F7939	SO READ THOUT TADE ASTACHMENTS	
ERRIFE GUTTU TAPE STOSSOSSOSSOS	ly.	201
Prof Portable	151 AO FORMATITIOF Solve April 1988	184
PETRONT1 9205-0205-0202	1	4 0
4202 DO 9203 B-10MCHT	3	781
SACON MARKET CUTPUT TAPE BIGAZOBOTRECOMO	2	
SOUR PORMATIFICA	•	0
9205 BPCNT=PTCNT+T		188
BF(@TCNP-NTIMES) 99-950-2		61
93 HOURETENETETENTS		100
READ INPUT TAPE SOLOGNIERTH	i	
WRITE OUTPUT TAPE 11.30. NAPATH . STYPE . SSN . SUNDER . MOUNT	. 1	7.4
SA POREATELORG - 65 / 11 8 F 5 6 R + F6 - 2 - 1 X - F5 6 2 6		

FDRMAT(13(194 FUNCTION FOE(SSN+COSX)
TE(TES(48+46+48	195 PF(COSX-0.3420) 1.2.2
AK WRITE OUTPUT TAPE 11.32. (ES.FREGL.FREOD.FREOH.ANGLL.ANGLD.ANGLM	196 1 FOE=0.0
AACO METE OUTBUT TAPE 11.3201.NCHT	197 RETURN
FENCHT) 47.44.4602	198 2 FOE=3.4e(1.0+0.009)essNiee0.25e(COSKee0.33)
4602 DO 4603 I=1.NCHT	199 RETURN
4603 WRITE OUTPUT TAPE 11,3204.HFRECILI)	200 END
47 ISETS=ISETS+1	192
(FIISETS-WSETS) 39.39.2	202
48 WRITE OUTPUT TAPE 11.45.1ES	203
READ IMP'IT TAPE 5.49.NPATCH	204
49 FDRHATC(4)	209
READ INPUT TAPE 5.50.(PSTART(I).PENDE().(=1.NPATCH)	206
FDRMAT(1X.2F9.2)	207
WRITE OUTPUT TAPE 11.49.NFATCH	208
WRITE OUTPUT TAPE 11.50.(PSTART(;).PEND(I(.)-1.NPATCH)	808
0D 52 1=1.MPATCH	210
READ INPUT TAPE 5.49.NPT	23
READ INPUT TAPE 5.51.4ESD(ST((.J).TFDES((.J).Jel.NPT)	22.
51 FORMAV(1X.FB.2.1X.F5.2)	215
WRITE OUTPUT TAPE 11.89.NPT	224
52 WRITE OUTPUT TAPE 11.91. (ESD(ST((.J).TFOES((.J).J=1.NPT)	219
WRITE DUTPUT TAPE 11.93.FRFOL.FRFOD.FREOM.ANSLL.ANGLD.ANGLH	216
53 FDRMAT(3F7-3/3F7-3)	217
60 10 4601	210
C	219

FUNCTION COSCH (PHIO, THETAO, T. PHIZ. ALPMA, DI	SUBROUTINE POLVIRIONIONZONDONDONDONDO
P1=2.1415927	X150=X1=X1
SINPHOESINF(PHIO)	x250mx2ex2
COSPHO=COSF (PH10)	X950=#3=X
COSALP=COSF(ALPHA)	6 D=X150e(X2-X3)-X1e(X250-X350)+fX250eX3-X350eX2)
SINPHI = SINPHO = COSF(D) + COSPHO = SINF(D) = COSALP	7 DI=VI=(X2-X3)-XI=(Y2-Y3)+(Y2=X3-Y3=X2)
COT=(SINPHO=COSALP-COSPHO=COSF(D)/SINF(D))/SINF(ALPMA)	D2=XISOe(Y2-Y3)-Y1e(X2SO-X3SQ)+(X2SQeY3-X3SQeY2)
ATANG=ATANF(1.0/COT)	03*X15Qe(X2eY3-X3eY2)-X1e(X25QeY3-X35QeY2)+Y1e(X25QeX3-X35QeX2)
IF(ALPHA-PI) 1,4.4	10 A=D1/D
1 [F(ATANG) 2:3,3	11 8=02/0
2 THETA1=THETA0+ATAMG	12 C=03/0
60 TO 7	13 RETURN
3 THETA1=THETAO+(ATANG-PI)	14 END
7 01 09	13
4 [FIATANG] 6.6.5	2
5 THETAL THETACATANG	2
5 0 10 7	
6 THETAL=THETAO+(PI+ATANG)	2.
7 THETA2*(T-12.0)*(3.141:927/12.0)	2
COSCHI=SINPH1=SINF(PHI2)+COSF(ATANF(SINPH1/SORTF(1.0-SINPH10-2)))	
1COSF(PHI2) COSF(THETA2-THETA1)	22
RETURN	2
END	**

STANFORD RAY TRACE PROGRAM	1 SUBROUTINE DUREF
SUBROUTINE UPREF	COMMON REFIND.FREG.FC.ITEFL.MI.M2.HM.YM.COSS
COMMON REFIND FREG. FO. IREFL. MI. M. S. MM. VM. COSI	3 IFIFO 201-2
IF(F0) 2.1.2	1 19671-9
1 IREFL#3	WINDS W
Н2вНМ+УМ	RETURN
ARTURA	7 REFIND-IFACO/POI-COSI
2 REFIND-(FREQ/FO)-COS!	1FIREFIND-1-01 3-4-9
IFTREFIND-1.03 30405	9 3 IRFF-1
9 IREFL#1	10 H3-HR-VH
HZBHMMYM	11 PETURN
RETURK	4 10671-4
. IREFLEC	19 RETURN
RETURN	14 9 IPEREPIND-2-01 7-7-6
S IFTREFIND-2.08 7.706	15 6 INFEL=5
A INFFL=9	16 H1=4H-VH
H2=HH+YH	17 AETURN
RETURA	16 7 1MEFL=2
2 3 2 5 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 7 5 7	19 извинем
M2-MK-YR	30 AETURN

CTANEDRO RAY PRACE PROGRAM	1 Is Reliable
	2 DP1-IFREG/FOISTH-LOST (IRETIND-1-01/PRETIND-1-01V
SUBROUTUNE PATH	BOD-GRANNIESTRFCANGLETI OPPI
COMMON REFINGSFREDSFOSSRRENGSRESSRESSRESSRESSESSESSESSESSESSESSESSES	DPPotroupiestuffangmioangment/51 wf tangmin
1.FMODE SMICALCORRORD OF 124 SMOOD SPRANCORPORATIONS CONTINUED TO SECOND SPRANCORPORATION OF THE SECOND SPRANCORPORATION OF	
2COSBROANGLET . 21000	
STREET COM PLOT 61903 of PHT 61901 STROPE 61901 of PARME (7)	
	4 60151-60157+(001-602)
PRODUCTION OF THE PRODUCTION O	BFINTGALCT 21.22.27
ARG2=COSBAZARANZ	21 18-61-01
PROTIES TERMINATION OF THE CONTRACT OF THE CON	
ANGWZBATANFLARGZYSORTF (1-0-ARGPBARGET)	•
PREFLOPREFL	
60 TO HILPOTIOREFL	122
	13 STATERIORI-ZODATA
	16 27 RETURN
IFTERNATOR Treezes	29 9 DP1-CR-H21-SENFTANGHI-ANGH216SENFTANGH13
11 GDIST=P1000+5000=0	
RETURN	
12 FHODE-10-BOFHODE-FLAVR	1
DPI-FFREA/FOR-VM-CLOGFEELS.DORFFRDEA/FISO-REPRODE	
BDE FRACE+SHIPLESTNFLANGLECTIONS	16 IF (HTCALCT STAZESS)
GANGH!	11 Gorcel
DD-BB-CANGHT-	21 Photicelecolst
	22 Platikelond
200 + (00) + (00)	29
	20 Straffictions
	25 32 PETUM
NEW EXP	35 Cub
16 KK=KK+1	£ .
1-GD\$ST-DD\$#2-0	2
FPHPIEKI-H2+YHPIB-0-SAPEFILS O-REFINDED	2
JF1LAVR-45 18918017	•
TH- 61-6-50R* 61	a

-	2	en	1	0	•	1-	a)	0	Oper	=	12	13	=	15	92	=	18	19	2	23	22	23	54	52	52	27
STAMFORD RAY PRACE DROGRAM	2 Deserteri-11,1419927/100.01=x	9 Aberer 111-1116-0/5-1-159271-H	4 Postetatetetet	S GRESSWEINP-ATANFERFES. 6-Nº 418	######################################	9 31014-04-milk-20193	P[030113907]	COMMENT BUSHY FOR TOMOSPHERIC GENERATORS	COMMON REFENO.PREG.FO.BREFE.ME. 12.MM.VM.CO.F.PDIST.GDESTOSHM.FRCMT	S. FRODE SHTESL C. KK. of 2DP of 2MP of RODE of NAME SANGHI SANGHZOL AVR. FLAVR. R.	SCOSER-ANGLES-PROCO	Demets 90% FROTEROD - FRITT -	nemsion frofizon. Trofizen, frefilen, futfact	PREFERSION NOTSTANDS -FOFZISSISHTESSS-FRUISSS-FXFZ6501	Dimension estantizes. Pencizes. Escassing a TFOEG828-108	DIMENSION ACDISTIZED - ABETARZEGS AMODEIZES	DIMENSION OLYTHI2001-BFREG420CB-FREGNM4329	DIMENSION MOLDMISSO.101.HOLDH985AB.HOLDBILS988MOLGGF99A1	DIMENSION HOLOTIISO1.HTLOGAISCE.HOLOAMISO4.HFREGFSOB	REWING LE	R=6367.0	1 READ IMPUT TAPFIL-2.FHMAME.ITYPE	2 FORMAT(1046-15)	JK-0	0-1X	IPEN=0
AS AND DAY WRICE PROGRAM	DISTRICT OF PERSONS SPECIAL SP	SUBROUTINE CALCIO	Man C. Contain a	THE PROPERTY OF THE PROPERTY O	#01-A(TADEXI	#02=A1 PROFIES	FINENCE INDEX	F0=F01+F110131=	RETURN																	

32 29 30 31 32

700 5 1=1+200 700 111+00-0 700 111+00-0 9 74111-0-0

	The second secon	
#0F2411=0.0	34 10 HT(1)+HTGUNF(FMU(1)/(FOF2(1))	
MT(1)=0.0	39 COMPENT GENERATE E LAYER	-
6 FWU(1)=0=0	36 1001 HME-120.0	i
[F(17YPE-1) 208.2)1.211	37 YME-20.0	
201 READ IMPUT TAPE11.202.PLENGT.FLAT.FLON.SER	0.000	
202 FORMAY(1X*F8*2*1X*F6*2*1X*F7*2*1X*F6*21	191	
READ INPUT TAPELL . 203 . SSM . DECSUM. T	40 SUMCOS-0-0	
203 FORMAY(1X6F5eleZx6F6e2e1X6F9e2)	11 1F(C-PLENGT) 12,12,13	
READ INPUT TAPEII-204.N	42 12 COSX+COSCH (FLATR,FLOMR,T.OECR,BERR,D/R)	
204 FORMAY(IX-13)	43 TFOE(1) oFOE(SSMoCOSX)	
READ IMPUT TAPELLO2050 (RDIST(11010-10M)	D•D+100.0	i
205 FORMAT(1XeF8.2)	1+1+1	
IF(MOPT) 206-209-206	46 IFFCOSX1 1201+1202+1202	
60 10 209	47 1201 COSX=0.0	
208 READ IMPUT TAPEIL.203.55M.DECSU.4.T	\$202 SUMCOS-SUMCOSA	4
209 READ INPUT TAPEILOZICO(FXF2(1)oFMU(1)ololoM)	60 70 11	
210 FORMAT(1X.F5.201X.F6.2)	30 13 ME-[-]	
60 10 219	91 AVCOS-SUMCOS/FLOATFINED	ļ
211 READ IMPUT TAPELLO202.PLEMGT.FLATOFLOM.DER	\$2 IF (AVCDS) 1290,1299,1980	
READ INPUT TAPELLO-203-55M-DECSUM-T	\$3 1299 COSCHI=C.0	
READ INPUT TAPEIL-204-N	\$4 6b 70 1301	
213 READ INPUT TAPELL-214-(RDISTILL-FAFZII)-WTITT-I-10M1	95 1900 COSCMI=COSF(0.8819ARCSINF(SQRTF(1.00-AVCOS+21))++1.3	
214 FORMATELX#F8+2+1X+F5+2+1X+F6+21	34 1901 DI=(1.0+0.0097=SSN)+CDSCM!	
215 FLATR-DEGRADFIFLATI	97 COMMENT GENERATE FI LAYER	
FLONR-DEGRAOF (FLON)	50 HMF1=210.0	
BERR-DEGRADF (AER)	96 VMF1=60.0	
OECR-DEGRAPF (DECSUM)	DO 14 1-15HE	
PFAV=1.0	61 14 TFOFICTIOFOFIFCTFOECEII	
DO 901 1-1-M	62 COMMENT GENERATE FZ LAVER	
901 FOF2(1)*FXF2(1)	69	

LIM=(MolV62 \$0 16 1=10LFW 41=101		
LIME(Melle/2 BO 16 1=1eLTM J1=Je1	96 COMMENT GENERATE ES LAYERS, IF ANY	130
#0 1# 1=1eLF# 41=101	99 READ IMPUT TAPEILES+1ES	181
100-100	100 29 FORMATIX+121	132
100-100	101	133
3.6.7		134
(PDJ=ROIST4J)/PLEMGF		135
DOLLI #ROI SO (JI) /PLENG®	103 PSTARTELEURO	
#URB 107 101 100 100 100 100 100 100 100 100	104 29 PENDIII=0.0	130
MOJ2 *KDISTICATION OF THE PROPERTY OF PARTY OF STANDARD OF CALL OF CAL	105 00 26 1=1.20	137
CALL POLITINGS OF SAME SAME SAME AS SAME AS SAME AS SAME AS SAME SAME	106 DO 26 J=1e10	130
CALL POLY(RDJentill) services and an arministration of the control	107 ESOIST(1.J)=0.0	139
1501 IP(ED/PLENGT)-RDJZI 100101	108 26 TF0ES(1.J)*0.0	140
16 X=OPPLFNGT	READ INPUT TAPETT . 27 . NPATCH	141
TFOP2(K)=((AleX+81)eX)+C3		142
THT(K)=(1A2*X+B21*X1+C2		143
D=D+100+0		144
	112 28 FORMAT(1X+2F9+2)	
	113 WRITE OUTPUT TAPE 6.280T	145
60 TO 1501	214 ZBOS FORMATCIHO-18HES PATCHES PRESENT/1HO-33HPATCH STARTS AT	PATCH 146
17 de 32		7147
18 CONTANUE	MRITE BUTPUT PAPE 6.2802.(PSTART#11.PEND(1).1=1.MPATCH)	146
00 19 1-4,200		149
JF0E411=TF0E(K=1)		150
TF0F\$(19=7F0F1(K-18		151
YFOF2(1)=TFOF2(K-1)	110 MEAD INPUT INPELLINGUINGS	
30 HP(1)=1H7(K-1)	120 29 FORMATI 1x-131	
LETTE ALTOH TAPE 6.20°FHNAME	321 READ INPUT TAPETL+50+(ESDIST(F+J)+TFOES(I+J)+J=1+NPTS!	ec.
TALLE COLLEGE DESCRIPTION FOR THE FOREST FOR THE FOREST FO	122 30 FORMATELES-2-18-5-24	131
20 FORMAL LINESCONDON	123 Soot CONTINUE	155
WRITE OLIVE THE WALL BOTH HT FOF 2 RANGES	124 31 HWES-180-A	156
	125 COMMENT ALPMA-MUMERIC COLIVALENTS OF NOSE REFLECTION NAMES	151
0=0=0	126 FRANCET 1=3M-ES	158
DO 2201 Jelek		159
WRITE OUTPUT TAPE 6.22-1FNE(J). IFOF16J). ITOFZTJ). IMITATO	!	160

- Contract Contract	162 COSES-COSF (ANGES)	194
Thomas and the same of the sam	103 RANGES-ROLDANGLF-ANGEST	195
3-15 1-0 1 HEX.	164 ANGE-ERCSINFICOSBR/INME+RIT	196
FRAMELY	165 COSECIOSFIANGE)	197
DISCONDING THE PROPERTY OF THE	MANGE OF COMMELE - ANGET	198
NA READ TRECORDER AND THE PROPERTY OF THE PROP	SAGE SORCESUR - COSOR PINE 10R9	199
READ LANCY	THE COSFIECOSFIANGELS	200
SZ TOWANT STATE OF A MGLE BANGE TO RE USED	160 RANGFIORSTANGFANGFIS	201
READ INDUT TAPETTOS SETAL SETADEBETAN	170 SECANG-1-0-5087F41-0-1C05FRFIR+79.018-029	202
00 FORMAT(1977.3)	171 60157-0.9	203
POURENT START MAY TRACING PORTION OF PROGRAM	1772 PDECTOROS	204
READ THPUT TAPE 11.9301.WCMF	179 SPCN700	205
STORMATCES	1	506
IFCHCHT9 3504-3304-9302		201
	176 Country UP-Golng Es Laven	208
11 PEAD INPUT TAPE 11-3303-HFREGITS	177 Saut fratesi 19,530,59	209
Son FormATEF7.3	176 30 8-n	210
	139 TOESTAGOESTAGES	211
101111011 12:32:11301	100	212
	282 Preg-Nobited alealads	213
	182 43 LF4TOf47-PSTART4811 66.48.69	214
P R C BULL N	205 42 PF\$TDEST-PENDERIT 43.40.40	215
O T	110 69 741	216
FM: 11501e36e21504	200 44 F(TDEST-ESDESTFE-JB) 46:46:45	712
The second secon	186 49 1-3-1	218
TAN .	107 69 10 44	219
NA PRIBLIA BETAND 30-38-9401	\$80 A6 FOINTFOES(I.J-19	220
SALMENT CALCIN ATE CONSTANTS FOR A GIVEN BETA	100 FO2-1F0F5(1-3)	221
AS ASTABADE BETAN	1990 Dief501ST11.J-11	222
CORRECOSTOBIAN	198 NEFESTITION	223
		334

47 REFIND=(FREQ/FO)+COSES			
	526	60 TO 59	258
48 IRCN1=IRCN1+1	227	61 F01=TF0FS(1+J-1)	526
1	228	FD2=TFDES(1+J)	260
FD - 04 - 04 - + - + - + - + - + - + - + - + - + -	\$28	D1=ESD1ST(1+J-1)	261
THE PROPERTY OF THE PROPERTY O	230	D2=E5D15T11+J)	262
[* * * * * * * * * * * * * * * * * * *	291	FD=FC1+((TDIST-D1)/(02-D1))+(F02-FD1)	263
F(A4×1100	282	IF(FO) 62,89.62	564
FMOODERFACUSE TO FINE TO ANGES / ASENT TO ANGE FO	233	62 REFIND= (FREG/FD) +COSES	592
CALL SANATA SANA	234	JF (REFIND-1.0) 63.89.89	266
	235	63 IRCNT=IRCNT+I	267
	236	IF(IRCNT-10) 6301.6301.93	268
TEGENIST - PINON 50-50-93	237	6101 LAYR=7	569
	862	FLAYR=7.0	270
50 Finite alcount	239	FMDDE=FMDDE=10=0+FLAYR	172
1	200	IFRMES=1	272
1014	241	DRI=(R+HI)+SINF(ANGES-ANGHI)/SIN(ANGES)	273
	242	DD1=R+(ANGES-ANGH1)	47.2
C LLCC LLCC LLCC LLCC LLCC LLCC LLCC L	243	PD1S1=PD1ST+DP1	275
52 ITEMSORIES	746	GD15T=GD15T+DD1	276
00 to 30	265	IF(GDIST-P1000) 64.64.93	772
53 IFRMESHO	266	64 IFIHTCALC) 65.66.69	278
GO TO 68	24.2	65 KK=KK+1	279
COMMENT DOWN-GOING TO LATER	243	FIDTIKK)=GDIST	280
54 [F([ES] 55.6/•25	546	FINTERS	281
555 1=0	250	RMODE (IRCNT)=FNAME (LAYR)	282
TOTAL STATE OF THE	146	66 GD TD 74	283
5501 1=1+1	253	67 GD TO 89	284
IF(I-NPATCH) 56.35.04			285
56 IFITDIST-PSTART(III 89.89.57	553	ا د	
57 IF(TDIST-PFND(1)) 58-5501-5501	554	60 Helike	987
5.8 J≈1	255	∃MA•MA	287
40 1E4TDEST-ESDIST(1.J)) 61.61.60	256	SHMEHM	288

cost*cose	290	STM=THS		322
11=0.0	291	ANGL E1 = ANGF 1	* * *	323
LAYR=2	292	COS; =COSF1		324
FLAYRe2.C	293	HISHEFFYEE		325
CALL CALCFOGDIST+RANGE.TFOE+FO1	762	IF(IFRMES) 75.76.75		326
I FRMES = 0	548	75 HISHMES		327
CALL UPREF	296	76 LAYR=3		328
F(REFL-4 69.93.69	297	FLAVR=3.0		329
69 CALL PATH	298	CALL CALCFOGGOTST+RANGF1+TFOF1+FO)		330
IREFLOIREFL	550	CALL UPREF		331
IFIGDIST-P10001 70.70.93	300	1F(1REFL-4) 77.93.77		332
70 GO TO (89,74,74), IREFL	301	77 CALL PATH		333
COMMENT DOWN-GOING F LAYER	\$05	IREFL=IREFL		334
71 HYSHME	303	IF(GOIST-B100n) 78.78.93		338
YME	304	78 GO TO (71.82.82). IREFL		336
SHM*-HM	305	COMMENT DOWN-GOING FI LAYER		337
ANGL EI . ANGE	306	79 HM=HMF1		338
COS1*COSE	307	V BE WHEN		339
H2=HMF]=VMF]	308	SHM S H	The second secon	340
LAYR=6	309	ANGLE1=ANGF1		341
FLAYR.6.0	310	COSI=COSF1		345
CALL CALCFOIGNIST+RANGF1+TFOE=FO)	116	H2=HMF2-VMF2		343
IFRMES=C	312	LAYR=5		344
CALL DWREF	913	FLAVR=5=0		345
IF (REFL-6) 72.93.72	314	TOIST*GDIST*R*(ANGF1-ARCSINF(CO3BR/(H2+R)))	BR/(H2+R)))	346
72 CALL PATH	315	CALL CALCFOITDIST, TFOF1, FOI		347
IREFL = IREFL	916	CALL DWREF		348
IF(GDIST-P1000) 73,73,93	116	JF (TRFFL-4) 80.93.80		346
73 GO TO (74.54.54).[REFL	916	B) CALL PATH		350
COMMENT UP-GOING FI LAVER	916	IRFFLOTREFL	1	351
	•	40 - 10 - 10 - 100 - 10 - 100		

1354 H2-HHF2-VHF2 1355 CALL PATH 1356 SECOND SECOND 1356 SECOND SECOND 1357 CONNECT TAKE BAY TO GROUND 1358 CONNECT TAKE BAY TO GROUND 1359 CONNECT TAKE BAY TO GROUND 1350 SECOND SECOND SECOND 1350 SECOND SECOND SECOND 1350 SECOND SECOND SECOND 1350 SECOND SECOND SECOND 1350 SECOND	81 GO TO (82,71,71),1REFL	353 67 [REFL=1	305
1959 GALL PATY 1950 19	COMMENT F2 LAYER		386
157 159 150 159 150 159 150	O-CHAUSE OR		387
1558 1570 1770	O O C THE CARRY		366
956 959 COMMENT TRACE RAY TO GROUND 960 954 965 965 965 1470-6 966 1870-7 966 1870-7 967 968 969 970 970 970 970 970 970 970 970 970 97			389
359 COWENT TRACE RAY TO GROUND 361 HEFFL-3 362 LAFFL-3 364 LAFFL-3 365 CALL PATH 1NTRP-1NTERP 365 GALL CALL 366 GALL CALL 367 GALL CALL 368 GALL CALL 368 GALL CALL 368 GALL CALL 368 GALL CALL 370 GALL CALL 371 AREFALLI-SETA 372 ANOMETILI-SETA 373 GALL CALL 374 GALL CALL 375 GALL CALL 376 GALL CALL 377 GALL CALL 378 GALL 378 GALL CALL 378 GALL 37	TOTAL TOTAL OF THE PARTY OF THE		390
360	CHIZL		166
363 1872 1872 1872 1872 1872 1873 1873 1873 1873 1873 1874 1874 1875 1	ANGHIE ARCSINF (COSBR/(P+ (HMF1+VMF1)))	and the state of t	392
16FEL=3 16FEL=3 17FEL=3 17FE	83 [F(ABSF(THMF2-HMF2)-10.D) 86.86.84	1	393
Layer 1963 Layer 1964 Layer 1964 Layer 1965 Laye	84)F(ICNT-20) 85.85.93		394
NFTCOSBA/TR+THME2 944 CALL PATH NFTCOSBA/TR+THME2 945 INTERP-INTERP NFTCOSBA/TR+THME2 945 INTERP-INTERP NFTCOSBA/TR+THME2 945 On Interpretation on interpretation of the property of the pro	BS HMF2=THMF2		366
INTERDISTRATED 365 INTERDISTREPDION 70,90,53 INTERDISTREPDION 20,90,53 INTERDISTREPDION 30,90,53 INTERDISTREPDION 30,90,53 365 365 365 365 365 365 365 365 365 375	CALL CALCFO(TD)ST.THT.THMF2)		396
Interest 1000 100	ANGH2=ARCSINF(COSBR/(R+THMF2))		397
NG NG NG NG NG NG NG NG	TOIST-TRANGE		398
1	TOANGE BOR LANGH 1 - ANGH 2)		399
1	TOLST=TDIST+TRANGE		904
11 12 13 14 14 15 15 15 15 15 15	ICNT=ICNT+1	į	4D1
AGDISTILL)=GDIST AGDISTILL)=GDIST	60 T0 83	1+17+11	402
IAMGF21 372 AMORETLL1=BETA IAMGF21 374 GO TO 1901 IAMGF21 374 GO TO 1901 IAMGF21 375 94 BETA=BETA+BETAD STR 94 GO TO 17 GO TO 37 GO TO 37 GO TO 37 GO TO 37 FZ 379 A 95 RHODE II 1= 6060 6060 60 FFI 380 JI=1 OCTOIST-TFOF 2.FO) 381 HTCALC=1 IEG/FOJ PCOSF 2 951 HTCAL=0 GO TO 95 L GO TO 37 AMORETIA = 6050 6060 60 AMCALC=1 IF IMCHT1 952 x 951,952 951 HTCAL=0 GO TO 95 L GO TO 97	BA HMF28-11MF2		403
373 A WORE (LL L = FMODE 374	COLUMN A CONTRACTOR A COLUMN A		*0*
GO TO 1801 374 975 976 976 976 977 978 978 978 978	COSED#COSE (ANGES)		404
975 99 GO TD (\$\$4.1001.)NTERP ANGF2 ANGF2	VEFOR CO. 4 / 1 0 4 1 8 HMF 2		90 *
ANGEZ 94 BETA=BETA+BETAD ANGEZ 378 GO TO 37 +YME1 379 A 95 RMONE (1) = 6 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0	6427		404
2 ANGEZ 5.78 GO TO 17 9401 00 95 4=10.10 1+7MF1 5.0 1+7MF1 5.0 5.0 1+7MF1 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0 5.0	H-RIDO AH-RIDO	94 BETA=BFTA+BETAD	804
#MGF2 #MGF2 #MGF2 # 95 RMONE(I)=6C636066060 # 95 RMONE(I)=6C636066060 ##CALC=1 ##CALC=0 ###CALC=1 ####CALC=1 ###################################	CHRYEN	60 70 17	604
379 A 95 RHONE [1] = 6.06.06.06.06.06.06.06.06.06.06.06.06.06	AMGIETAMORZ	9401 00 95 8=1-10	410
\$6.0 ALCFO(TOIST.TFOFZ.FO) \$82 ALCFO(TOIST.TFOFZ.FO) \$83 \$951 HTCAL-0 \$951 HTCAL-0 \$952 \$854 \$954 HTCAL-0		•	411
4-D ALCFORTOIST-TFOFZ-FO) 383 951 HTCALC=1 1FINCHT) 952-951-952 951 HTCAL=0 951 HTCAL=0 953 GD 50 9501	1		412
382 JFINCHT) 952-051-952 383 951 HTCAL-0 584 GD TO 9501			413
389 951 HTCAL=n GD 40 9501	CALL CALCEDITOTST-TFOFZ-FO)		414
1056 O1 O5 +986	PERION FEEDVED COSE2		419
	10 10 10 10 10 10 10 10 10 10 10 10 10 1	•	416

- 68 -

	HOLDT(KL)=TIME	
IF(FREQ-HFREG(1)) 953,954,953	419 HOLDOKKL)=6015T-PLENGT	
953 CONTINUE	420 HOLDB(KL)=08	1
HTCAL=0	FLONO*-FLON	
60 10 9501	1F(HTCAL) 108,1085,108	1
OSG HTCAL®1	901	1
OFO1 1F(11-(LL-1)) 9502.9502.9901		
7501 : FIRMODE(11)-AMODE(11+1)) 99,96,99		i
OA 1E (AGD)ST(11)-PLENGT) 99.97.97	FORWATCING SHMODE	
•	RRITE OUTPUT TAPE	
OR BETA-ABETA(II)+((PLENGT-AGDIST(II))/(AGDIST(II+1)-AGDIST(II)))	1082	
1. CARTA(11+1)-ARETA(11)		
2 m G M G M G M G M G M G M G M G M G M G	1083	
60 10 38	250 1084 FORMAT(140+F6=2+F10+2)	
99 11=11+1		
GD TO 9501		
990] FREG=FREG+FREOD		
60 10 34	112	
2. C.		
100 IF1601:		
GDIST= (PLENG 12. 10. 10. 10. 10. 10. 10. 10. 10. 10. 10		
102 IF(FMODESAMODE(111) 3741030	438 FLONO=FLON	
104 FORMAT(1H1-1DAN)		
103 D8=515-5-51-FICAL FIRSTH-F9-2-3H KM-58-7HTM LAT -F7-2-6H DEG-5M-	440 WRITE OUTPUT TAPE 0+110	
FORMALITATION OF STATE OF STAT	THE FORMATCHES AND ACT TIME	
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JK=JK+1 ************************************		ALLKI
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2 10/07	446 118 FORWATTITION CONTINUES	
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CHOCKET		

No. 10. No.	C PRO	IONOSPHERIC PROFILE FOR		6 OCTOHER 1962 1737.36 GMT PAHOA/BEOFORD PATH	2.9	0.4	7.6	232.37	2800.00	3.1	4.	7.7	250.19	5803.00
29.1.3.1 1.00.00 2.0 4.0 7.5 220.31 310.30 31.1 4.4 7.7 254.40 20.1.3.1 100.00 2.0 4.1 7.5 220.01 31.1 4.4 7.8 250.40 210.01 300.00 2.0 4.1 7.5 220.00 3.1 4.4 7.8 250.40 210.01 300.00 2.0 4.1 7.5 220.00 3.1 4.4 7.8 250.40 213.23 4.00.00 2.0 4.1 7.5 220.00 3.1 4.4 7.8 250.40 213.23 4.00.00 2.0 4.1 7.5 220.00 3.1 4.4 7.8 260.10 213.23 4.00.00 3.0 4.2 7.5 210.00 3.1 4.4 7.8 260.10 220.23 4.00.00 3.0 4.2 7.5 210.00 3.1 4.4 7.8 260.10 220.24 4.00.00 3.0	FOF2		. F OF 2	RANGE	5.9	4.0	7.5	231 - 35	2900.00	3.1	4.	7.7	252.39	2900.00
208-03 200-04 4.1 7.5 220-14 317-06 31.1 4.6 7.8 250-06 210-37 200-03 200-03 3.1 4.0 7.1 7.5 227-06 3.1 4.0 7.8 7.8 250-06 210-37 400-03 2.0 4.1 7.5 227-06 3.1 4.4 7.8 250-36 213-37 400-03 2.0 4.1 7.5 227-08 3.0 7.1 4.6 7.8 250-06 213-35 400-03 2.0 4.1 7.5 210-03 3.1 4.6 7.8 260-06 221-35 400-00 3.0 4.1 7.5 210-03 3.1 4.6 7.8 260-03 221-35 400-00 3.0 4.1 7.5 210-03 3.1 4.6 7.8 260-03 221-35 4.1 4.2 7.5 210-03 3.1 4.7 7.8 260-03 222-34 4.1<	7.5		55.50	•0	5.9	4.0	7.5	230.27	3060.30	3.1	4.4	1.1	254.49	90-6399
219.37 200.00 2.9 4.1 7.5 227.05 31.0 4.4 7.8 259.39 219.37 400.00 2.9 4.1 7.5 222.08 3970.00 3.1 4.4 7.8 259.38 213.32 400.00 2.9 4.1 7.5 222.00 3.1 4.4 7.8 259.38 213.32 400.00 2.9 4.1 7.5 220.00 3.1 4.4 7.8 259.38 213.32 400.00 2.9 4.1 7.5 219.09 390.00 3.1 4.4 7.8 269.39 224.37 400.00 3.0 4.2 7.5 218.07 390.00 3.1 4.6 7.8 269.20 224.37 100.00 3.0 4.2 7.5 218.07 390.00 3.1 4.6 7.9 269.40 233.44 110.00 3.0 4.2 7.5 218.0 390.00 3.1 4.6 7.9 4.6	7.5		107.13	100.00	5.9	4.1	7.5	229.14	3100.00	3.1	4.4	7.8	255.48	6150.33
1313.23 400.00 2.9 4.1 7.5 224.04 310.00 3.1 4.4 7.8 26.13 213.23 400.00 2.9 4.1 7.5 222.00 3.1 4.4 7.8 26.13 213.23 400.00 2.9 4.1 7.5 218.00 3.1 4.4 7.8 26.13 213.33 400.00 3.0 4.1 7.5 218.00 3.1 4.4 7.8 26.13 223.34 400.00 3.0 4.2 7.5 218.00 3.1 4.4 7.8 26.13 223.38 400.00 3.0 4.2 7.5 218.00 3.1 4.4 7.8 26.13 233.33 1200.00 3.0 4.2 7.5 218.00 3.2 4.4 7.8 26.18 233.13 1200.00 3.0 4.2 7.5 218.00 3.2 4.4 7.9 26.18 241.31 1300.00 3.0 4.2 <td>7.5</td> <td></td> <td>66.80</td> <td>200-00</td> <td>5.9</td> <td>;</td> <td>7.5</td> <td>227.96</td> <td>3230.00</td> <td>3.1</td> <td>4.4</td> <td>7.8</td> <td>258.36</td> <td>6200.00</td>	7.5		66.80	200-00	5.9	;	7.5	227.96	3230.00	3.1	4.4	7.8	258.36	6200.00
13.3.3 400.00 2.9 4.1 7.5 22.7.% 34.9.0.0 3.1 4.4 7.8 26.7.% 213.7.3 500.00 3.0 4.1 7.5 219.9 3500.00 3.1 4.4 7.8 26.7.% 213.7.3 500.00 3.0 4.2 7.5 219.9 3500.00 3.1 4.4 7.8 26.7.% 221.3.3 700.00 3.0 4.2 7.5 219.00 310.00 3.1 4.4 7.8 26.7.% 222.4.57 900.00 3.0 4.2 7.5 219.00 310.00 3.1 4.4 7.8 26.7.% 223.4.6 1100.00 3.0 4.2 7.5 219.00 310.00 3.1 4.4 7.9 26.9% 233.4.7 1100.00 3.0 4.2 7.5 219.00 3.2 4.4 7.9 26.9% 241.7 1100.00 3.0 4.2 7.5 222.00 4.0 7.9 26.9%<	7.5		10.97	300.00	5.9	4. 1	1.5	224.88	3370.00	3.1	4.	7.8	260.13	6360.00
13.13.45 600.00 2.9 4.1 7.5 219.09 3500.00 3.1 4.4 7.8 264.08 221.35 600.00 3.0 4.1 7.5 218.07 3.11 4.4 7.8 264.08 221.35 700.00 3.0 4.2 7.5 218.70 3.1 4.4 7.8 264.08 223.33 100.00 3.0 4.2 7.5 218.70 3.1 4.4 7.9 264.70 239.14 100.00 3.0 4.2 7.5 218.70 3.10 4.4 7.9 264.70 239.14 100.00 3.0 4.2 7.5 218.70 3.1 4.4 7.9 264.90 239.14 1100.00 3.0 4.2 7.5 222.00 3.1 4.4 7.9 264.90 241.31 1300.00 3.0 4.2 7.5 222.00 3.1 4.4 7.9 264.90 242.31 1400.00 3.0	7.5		113.23	400.00	5.9	4.1	1.5	222.06	3479.30	3.1	4.4	7.8	261.79	6400.00
213.45 600.00 3.0 4.1 7.5 218.47 30.3.50 3.1 4.4 7.8 264.26 221.39 710.20 3.0 4.2 7.5 218.77 350.00 3.1 4.4 7.8 264.36 224.57 800.00 3.0 4.2 7.5 219.27 390.00 3.2 4.4 7.9 264.80 239.38 1000.00 3.0 4.2 7.5 219.20 390.00 3.2 4.4 7.9 264.80 239.44 1100.00 3.0 4.2 7.5 219.20 390.00 3.2 4.4 7.9 264.80 239.44 1100.00 3.0 4.2 7.5 222.00 390.00 3.2 4.4 7.9 264.80 245.74 1400.00 3.0 4.2 7.5 222.00 390.00 3.2 4.4 7.9 264.90 245.74 1400.00 3.0 4.2 7.5 222.00 4.4 7.0 <td>9.</td> <td></td> <td>215.73</td> <td>00 • 00 5</td> <td>5.9</td> <td>4.1</td> <td>1.5</td> <td>219,99</td> <td>3500.00</td> <td>3.1</td> <td>4.4</td> <td>7.8</td> <td>264.08</td> <td>60°0'059</td>	9.		215.73	00 • 00 5	5.9	4.1	1.5	219,99	3500.00	3.1	4.4	7.8	264.08	60°0'059
229.28 900.00 3.0 4.2 7.5 112.0 31.0 4.2 7.5 112.0 31.0 4.2 7.5 112.0 31.0 4.2 7.5 112.0 31.0 4.2 7.5 211.27 350.00 31.2 4.4 7.9 267.00 239.28 900.00 3.0 4.2 7.5 210.27 300.00 3.2 4.4 7.9 269.70 239.28 1100.00 3.0 4.2 7.5 210.27 4.0 7.9 269.70 239.10 1100.00 3.0 4.2 7.5 220.00 3.2 4.4 7.9 269.40 245.10 1100.00 3.0 4.2 7.5 220.00 3.2 4.4 7.9 269.40 245.10 1100.00 3.0 4.2 7.5 220.00 3.2 4.4 7.9 267.50 245.10 1100.00 3.0 4.2 7.5 220.00 3.2 4.4 7.9 <t< td=""><td>7.6</td><td></td><td>218.45</td><td>00.009</td><td>3.0</td><td>4:1</td><td>7.5</td><td>218.67</td><td>3030.00</td><td>3.1</td><td>4.4</td><td>7.8</td><td>265.26</td><td>6650.00</td></t<>	7.6		218.45	00.009	3.0	4:1	7.5	218.67	3030.00	3.1	4.4	7.8	265.26	6650.00
229.28 900.00 3.0 4.2 7.5 219.27 350.00 3.2 4.4 7.9 269.70 239.28 900.00 3.0 4.2 7.5 219.20 3.2 4.4 7.9 269.70 239.33 1200.00 3.0 4.2 7.5 219.20 3.2 4.4 7.9 269.90 239.44 1100.00 3.0 4.2 7.5 21.0 3.2 4.4 7.9 269.90 239.19 1200.00 3.0 4.2 7.5 222.0 4100.00 3.2 4.4 7.9 269.90 241.01 1300.00 3.0 4.2 7.5 222.0 4100.00 3.2 4.4 7.9 269.90 242.79 1400.00 3.0 4.2 7.5 222.0 4100.00 3.2 4.4 7.9 269.90 242.79 1400.00 3.0 4.2 7.5 224.96 440.00 3.2 4.4 7.9 269.90	7.6		221.39	700.00	3.0	4.2	7.5	218.49	3700.00	3.1	4.4	7.8	267.83	6730.30
239,28 900,00 3.0 4.2 7.5 1970,00 3.2 4.2 7.5 1970,00 3.2 4.2 7.5 219,20 3.0 4.2 7.5 229,40 3.0 4.2 7.5 229,40 3.2 4.6 7.9 264,96 239,44 1100,00 3.0 4.2 7.5 222,00 3.2 4.6 7.9 264,57 241,01 1200,00 3.0 4.2 7.5 222,00 3.2 4.7 262,00 3.2 4.6 7.9 264,57 241,01 1300,00 3.0 4.2 7.5 222,49 400,00 3.2 4.6 7.9 264,59 242,79 1400,00 3.0 4.2 7.5 222,49 400,00 3.2 4.6 8.0 264,49 242,79 1400,00 3.0 4.2 7.5 224,48 470,00 3.2 4.6 8.0 264,49 242,79 1400,00 3.0 4.2	7.6		224.57	00.008	3.0	4.2	1.5	215.27	3500.00	3.2	4:4	4.1	269.79	6800.00
233.34 1200.00 3.0 4.2 7.5 227.07 400.00 3.2 4.6 7.9 266.57 233.46 1100.00 3.0 4.2 7.5 222.05 4100.20 3.2 4.6 7.9 267.55 233.19 1200.00 3.0 4.2 7.5 222.05 4100.20 3.2 4.6 7.9 267.55 241.01 1300.00 3.0 4.2 7.5 222.06 4200.00 3.2 4.7 7.9 267.59 242.79 1500.00 3.0 4.2 7.5 222.06 400.00 3.2 4.7 7.9 267.79 242.79 1500.00 3.0 4.3 7.6 227.05 4.7 7.9 267.75 242.79 1500.00 3.1 4.3 7.6 227.05 3.2 4.4 7.9 267.15 242.78 1500.00 3.1 4.3 7.6 227.03 3.2 4.4 8.0 267.15 <t< td=""><td>7.6</td><td></td><td>229.28</td><td>co*006</td><td>3.0</td><td>4.2</td><td>7.5</td><td>219.20</td><td>3900-006</td><td>3.2</td><td>4.4</td><td>7.9</td><td>264.96</td><td>00°u669</td></t<>	7.6		229.28	co*006	3.0	4.2	7.5	219.20	3900-006	3.2	4.4	7.9	264.96	00°u669
233.64 1100.00 3.0 4.2 7.5 222.05 4100.20 3.2 4.4 7.9 267.55 233.19 1230.10 120.00 3.0 4.2 7.5 222.06 4200.20 3.2 4.4 7.9 267.95 241.01 1300.00 3.0 4.2 7.5 223.06 430.00 3.2 4.4 7.9 265.96 242.73 1400.00 3.0 4.2 7.5 223.96 440.00 3.2 4.4 7.9 265.96 242.73 1500.00 3.0 4.9 7.5 223.96 440.00 3.2 4.4 8.0 265.96 242.73 1500.00 3.0 4.9 7.5 223.96 400.00 3.2 4.4 8.0 265.76 242.73 1500.00 3.0 4.3 7.6 227.86 477.90 3.2 4.4 8.0 265.76 242.74 1000.00 3.0 4.4 4.7 4.7 4.	7.6		233.33	1000.00	3.0	4.2	7.5	76. 222	4000.00	3.2	4.4	6.7	268.57	7.55.33
241.91 1270.00 3.0 4.2 7.5 222.96 4.700.00 3.2 4.4 2.20.96 4.700.00 3.2 4.4 7.9 4.7 9.0 9.0 9.0 9.0 4.7 9.0 9.0 9.0 9.0 9.0 9.0 9.0 9.0<	7.6		235.64	1199.00	3.0	4.2	7.5	222.05	4100-00	3.2	4.4	7.9	267.55	7133.90
241.01 1300.00 3.0 4.2 7.5 223.90 430.00 3.2 4.4 7.9 523.90 4.0 4.0 7.9 6.2 4.0 4.0 4.0 7.0 6.2 4.0 4.0 4.0 4.0 6.0	7.6		239.19	1200.00	3.0	4.2	7.5	222.96	4200.39	3.2	4.4	7.9	265.49	7200,00
242.77 1400.00 3.0 4.2 7.5 222.85 44°5.03 3.2 4.4°5.03 3.2 4.4°5.03 3.2 4.4°5.03 3.2 4.4°5.03 3.2 4.4 8.0 262.29 242.39 1500.00 3.0 4.3 7.6 225.45 4500.03 3.2 4.4 8.0 260.78 242.39 1600.00 3.1 4.3 7.6 227.88 4705.00 3.2 4.4 8.0 260.78 243.39 1700.00 3.1 4.3 7.6 227.88 4705.00 3.2 4.4 8.0 257.16 243.39 1900.00 3.1 4.3 7.6 227.88 470.00 3.2 4.4 8.0 257.15 242.87 1900.00 3.1 4.3 7.7 227.97 500.00 3.2 4.4 8.1 256.25 242.87 240.00 3.2 4.4 4.3 7.7 235.12 510.00 3.2 4.4 8.1	7.6		241.91	1300.00	3.0	4.2	7.5	223.90	4301.00	3.2	4.4	4.1	263.96	7330.30
242.39 1500.00 3.0 4.3 7.5 225.45 4500.00 3.2 4.4 6.0 260.78 241.97 1600.00 2.0 4.3 7.6 225.45 4620.00 3.2 4.4 8.0 269.41 242.79 1700.00 3.1 4.3 7.6 227.48 477.09 3.2 4.4 8.0 259.41 243.30 1800.00 3.1 4.3 7.6 227.48 477.09 3.2 4.4 8.0 259.41 243.33 1900.00 3.1 4.3 7.6 237.41 49.0.00 3.2 4.4 8.0 257.15 242.87 240.00 3.1 4.3 7.7 232.49 49.0.00 3.2 4.4 8.1 255.25 240.50 220.00 3.2 4.3 7.7 232.47 50.00 3.2 4.4 8.1 255.45 240.50 220.00 220.00 3.2 4.4 8.1 255.40	7.6		242.07	1400.00	3.0	4.2	7.5	224.85	60.00.44	3.2	4.4	8.0	262.29	7499.30
241.97 1600.05 3.0 4.3 7.6 225.48 4620.05 3.2 4.4 8.0 259.41 242.79 1730.00 3.1 4.3 7.6 227.88 470.09 3.2 4.4 8.0 259.41 243.30 1800.00 3.1 4.3 7.6 224.93 49.00.00 3.2 4.4 8.0 257.15 243.30 1800.00 3.1 4.3 7.6 224.93 49.00.00 3.2 4.4 8.1 256.25 241.93 1900.00 3.1 4.3 7.7 235.12 50.0.0 3.2 4.4 8.1 256.25 241.93 2100.00 3.1 4.3 7.7 235.12 5100.00 3.2 4.4 8.1 255.50 235.12 2500.00 3.1 4.3 7.7 237.25 5100.00 3.2 4.4 8.1 255.50 235.12 2500.00 3.1 4.3 7.7 24.58 500.00	7.6		242.39	1500.00	3.0	4.3	1.5	225.45	4500.00	3.2	4.4	8.0	263.78	7503.00
242.79 1700.00 3.1 4.3 7.6 227.88 470.00 3.2 4.4 8.0 254.20 243.30 1800.00 3.1 4.3 7.6 222.93 49.00.00 3.2 4.4 8.0 254.25 243.33 1900.00 3.1 4.3 7.6 232.97 49.00.00 3.2 4.4 8.0 255.25 241.93 1900.00 3.1 4.3 7.7 232.97 50.00.00 3.2 4.4 8.1 255.55 240.86 2200.00 3.1 4.3 7.7 237.12 5100.00 3.2 4.4 8.1 255.50 235.12 2500.00 3.1 4.3 7.7 237.25 5200.00 3.2 4.4 8.1 255.50 235.12 2500.00 3.1 4.3 7.7 241.45 5400.00 3.2 4.4 8.1 255.50 235.12 2500.00 3.1 4.3 7.7 24.55 5500.00 3.2 4.4 8.1 8.5 8.0 8.0 8.0 8.0	7.6		241.97	1600.00	3.0	4.3	1.6	225.45	4630.39	3.2	4.4	8.0	259.41	7600-00
243.30 1800.00 3.1 4.3 7.6 224.33 4830.00 3.2 4.4 8.0 257.15 243.33 1900.00 3.1 4.3 7.6 237.31 49.0,00 3.2 4.4 8.1 256.25 242.87 2000.00 3.1 4.3 7.7 232.97 5000.00 3.2 4.4 8.1 256.25 240.80 2200.00 3.1 4.3 7.7 235.12 5100.00 3.2 4.4 8.1 255.50 236.58 2200.00 3.1 4.3 7.7 237.25 5200.00 3.2 4.4 8.1 255.50 235.18 2400.00 3.1 4.3 7.7 241.45 5400.00 3.2 4.4 8.1 255.50 234.25 2500.00 3.1 4.3 7.7 243.56 5400.00 3.2 4.4 8.1 255.50 234.25 2500.00 3.1 4.4 7.7 243.58 5500.00 3.1 4.4 7.7 243.58 5500.00 235.33.34 2700.00	7.6		242.79	1730,00	3.1	4.3	1.6	227.88	4105.00	3.2	4.4	8.3	258.20	7790.09
243.33 1900.00 3.1 4.3 7.6 233.31 49.9.0.0 3.2 4.4 8.1 256.25 242.87 2000.00 3.1 4.3 7.7 232.97 5000.10 3.2 4.4 8.1 256.25 241.93 2100.00 3.1 4.3 7.7 235.12 5170.00 3.2 4.4 8.1 255.50 236.18 2200.00 3.1 4.3 7.7 237.25 5200.00 3.2 4.4 8.1 255.50 235.12 2400.00 3.1 4.3 7.7 241.45 5400.00 3.1 4.3 7.7 241.45 5400.00 234.25 2500.00 3.1 4.3 7.7 243.52 5500.00 3.1 4.4 7.7 247.87 5700.00 233.34 2700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00	7.6	٠,	243.30	1900.00	3.1	4.3	7.6	225.93	4830.93	3.2	4.4	8.0	257.15	7800.00
242.87 2000.00 3.1 4.3 7.7 232.97 5000.00 3.2 4.4 8.1 255.50 241.93 2100.00 3.1 4.3 7.7 235.12 5100.00 3.2 4.4 8.1 255.50 240.50 2200.00 3.1 4.3 7.7 237.35 5200.00 3.1 4.3 7.7 241.45 5400.00 235.12 2500.00 3.1 4.3 7.7 241.45 5400.00 3.1 4.3 7.7 247.56 5500.00 234.25 2500.00 3.1 4.3 7.7 247.56 5500.00 3.1 4.4 7.7 247.56 5500.00 233.34 2700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 7.7 247.87 5700.00 3.1 4.4 4.7 4.4 <td>7.6</td> <td>۰,0</td> <td>243.33</td> <td>1900.00</td> <td>3.1</td> <td>4.3</td> <td>7.6</td> <td>230.91</td> <td>49°0,30</td> <td>3.2</td> <td>4.4</td> <td>8.1</td> <td>256.25</td> <td>7960.00</td>	7.6	۰,0	243.33	1900.00	3.1	4.3	7.6	230.91	49°0,30	3.2	4.4	8.1	256.25	7960.00
241,93 2100,00 3.1 4.3 7.7 235.12 5100,00 3.2 4.4 8.1 255.50 240,50 2200,00 3.1 4.3 7.7 237.35 5200,00 235.12 2500,00 3.1 4.3 7.7 241.45 5400,00 234.25 2500,00 3.1 4.4 7.7 245.56 5600,00 234.25 2600,00 3.1 4.4 7.7 245.56 5600,00 234.25 2500,00 3.1 4.4 7.7 245.56 5600,00 234.25 2500,00 3.1 4.4 7.7 245.56 5600,00 233.34 2700,00 3.1 4.4 7.7 247.87 5700,00	7.6	٠,	242.87	2030.36	3.1	4.3	1.1	232.97	\$600.00	3.2	4.4	8.1	255.50	800c•u0
240.50 2200.00 3.1 4.3 7.7 237.75 238.58 23C0.00 3.1 4.3 7.7 239.36 235.12 2500.00 3.1 4.3 7.7 241.45 234.25 26.00.00 3.1 4.3 7.7 743.52 233.34 2700.00 3.1 4.4 7.7 247.87	7.6	vo	241.93	2150,30	3.1	4.3	7.7	235.12	5100.30	3.2	4.4	8.1	255.50	8130.00
238.58 23Cc.00 3.1 4.3 7.7 239.36 235.18 2400.00 3.1 4.3 7.7 241.45 235.12 2500.00 3.1 4.3 7.7 241.45 234.25 2600.00 3.1 4.4 7.7 24.58 233.34 2700.00 3.1 4.4 7.7 247.87	7.6	•	240.50	2200.00	3.1	* •3	7.7	237.25	5200.00					
235.18 2400.00 235.12 2500.00 334.25 2600.00 334.25 2600.00 333.34 2700.00 333.34 2700.00		•	238.58	2366.30	3.1	4.3	7.7	239.36	5360.00					
235.12 2500.00 234.25 2600.00 334.25 2600.00 333.34 2700.00 33.1 4.4 7.7 247.87		9	235.18	2400.00	3.1	4.3	7.7	241.45	5400.00					
234.25 26:00.00 233.34 2700.00 3.1 4.4 7.7 247.87		9	235.12	2500.00	3.1	4.3	7.7	243.52	00.0058					
233.34 2700.00		9	234.25	26.)5.00	3.1	4.4	7.7	2458	>639.30					
		•	233.34	2700.00	3.1	4.4	7.7	247.87	5703.33					

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6 OCTOBER	1962	1737.36	GMT	PAHDA/8EOFDRD	PATH

PA7H	LENG7H	804	5.35 K	н	TX LAT	19.	50 OES		T X	LONG	-154.95	0E G	RX 8EA	RING	50.26 0	E G
			R	00E							FREO	8E7A	OIST	TIME	01FF	08
•E	. E	. E	• E								4.00	1.18	8039.09	27.10	-6.26	649.57
.F2	• E	.€	• E	•E	.E	• E	• E	. E		. E	4.00	13.19	8041.41	27.98	-3.94	894.86
•€	.€	. €	. E								5.00	1.22	8037.90	27.09	-7.45	417.28
. E	•E	• E	•E								6.00	1.28	8036.66	27.09	-8.69	290.56
.€	.€	٠É	. E								7.00	1.35	8035.48	27.09	-9.87	213.86
.F2	• E	• E	• E	. €	•E	• E	•E	• E			7.00	12.50	8026.50	27.84	-18.85	275.91
• E	.€	. E	•E								8.00	1.44	6034.57	27.69	-10.76	163.91
• E	• E	. E	• E								9.00	1.54	8034.34	27.10	-11.01	129.54
• E	. E	•€	• E								10.00	1.68	8035.43	27.12	-9.92	104.55
. F 2	.F2	. F 2	. F 2	. F 2	.F2	. F 2					16.90	23.19	8015.76	30.17	-29.59	66.07
.t	•E	. E	. E								11.00	1.85	60 39.26	27.16	-6.09	86.48
. F 2	•F1	.F1	.F1	.F1							11.90	13.20	1989.22	28.10	-56.13	60.34
.F2	.F2	.F2	. F2	.F2	.F2	. F 2					11.30	21.70	8024-19	29.87	-21.17	57.77
.F2	.F2	. F 2	•F2	.F2	. F 2	.F2	• F 2				11.60	24.17	8041.84	30,53	-3.51	69.41
• F1	.€	. E	. F	• E							12.00	7.01	8043.03	27.63	-2.32	71.98
. F 2	.F2	.F2	•F2	.F2	.F2						12.00	18.43	8021.89	29.23	~ 23.46	47.56
.F2	.F2	.F2	.F2	. F 2	. F 2	. F 2					12.00	20.90	8040.18	29.80	-5.17	50.14
.F2	.F2	. F 2	.F2	. F 2	•F2	. F 2	.F2				12.00	23.91	8042.95	30.45	-2.40	51.30
.+2	.F2	. F 2	.F2	•F2							13.60	15.03	8042.09	28.85	-3.26	39.52
. + 2	.F2	. F 2	. F 2	. F 2	•F2						13.00	17.66	6031.97	29.15	-13.38	41.76
• F2	.*2	.F2	. F2	•F2	•F2	• F 2					13.00	20.65	6042.70	29.77	-2.65	43.22
.F2	.F2	•F2	• F 2	.F2	. F Z	. F 2	.F2				13.00	24.35	6037.02	30.58	-0.33	43.13
.F2	.F2	. F 2	. F 2	. F 2							14.50	14.17	89 38. 79	28.68	-6.56	35.63
•F2	.F2	.F2	•F?	. F 2	.F2						14.CO	17.32	8037.78	29.13	-7.57	36.79
• # 2	.F2	.F2	• F 2	,F2	.F2	•F2					14.00	20.86	6048.51	29.87	3.15	37.01
•F2	.F2	.F2	•F2								15.00	10.72	e018.50	28.16	-26.85	29.89
•F2	•F2	.F2	.F2	. F 2							15.00	13.72	8033.63	28.57	-11.72	31.79
•F2	.F2	.+2	.F2	.F2	.F2						15.00	17.35	8042.26	29.18	-3.09	32.05
.F2	.F2	. F 2	•F2	.F2	.F2	. F2					15.00	22.10	8045.07	30.17	-0.28	30.80
.F2	.F2	. F 2	. F 2								16.00	10.03	6044.89	28.24	-0.46	27.36
. F2	.F2	. F 2	. F 2	1 6 2							16.00	13.52	8036.26	28.56	-9.09	29.27
. F 2	.F2	.F2	.F2		.F2						16.00	17.82	8047.48	29.33	2.13	27.63
•F2	.F2	. F 2									17.00	6.29	8026.02	27.85	-19.33	22.57
. F 2	.F2	.F2	•F2								17.00	9.65	8040.63	28.17	-4.72	24.79
.F2	.F2	•F2	. F 2	.F2							17.00	13.56	8043.77	28.63	-1.58	25.01
.F2	.F2										18.00	0.26	8055.64	27.74	10.29	16.68
•F2	.F2	.F2									18.00	5.64	8746.42	27.92	1.07	20.88
•F2	.F2	.F2	•F2								18.00	9.49	8042.59	28.17	-2.76	77.35
. F2	.F2	•F2	.F2	. F2							18.00	13.91	8040.59	28.69	-4.76	21.95
.F2	•F2	.F2									19.00	5.28	8040.53	27.84	-4.62	19.12
•F2	•F2	.F2	.F2								19.00	9.51	8042.76	26.18	-2.59	20.05
. F2	• F 2	.F2	.F2	•F2							19.00	15.25	8033.20	28.90	-12.15	18.44
•F2	.F2	.F2									20.00	5.08	8042.24	27.84	~3.11	17.45
•F2	.F2	. F 2	.F2								20.00	9.73	8042.64	28.22	-2.71	17.89
•F2	.F2	. F 2									21.00	5.02	8044.62	27.86	-0.73	15.90
.F2	.F 2	.F2	. F 2								21.00	10.22	8045.00	28.32	-0.35	15.80
•F2	.F2	.F2									22.00	●.09	8042.56	27.86	-2.79	14.45
.F2		.F2										5.29			-7.54	
+F2		.F2											6740.43			
•F2	.F2	•F2									25.00	6.71	8016.11	27.91	-29.24	10.27

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6 OCTOBER 1962 1737.36 GMT PAHOA/BEOFORO PATH 7X LONG ~154.95 DEG RX BEARING 50.26 DEG
               PATH LENGTH 8045.35 KM TX LAT 19.50 DEG
                             MODE .F2 .F2 .F2 .F2 .F2 .F2
                                         18.426 DEGREES
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                                                                                                                  •
         TX LAT 19.50 DEG TX LONG -154.95 DEG RX BEARING 50.26 DEG
6 OCTOBER 1962 1737.36 GMT PAHOA/8EOFORO PATH
                          MODE .F1 .E .E .E .E
                                     7.005 DEGREES
              PATH LENGTH 8045.35 KM
                                                                                                                                                                                                8043.03
                                                                                      1928.36
                                                                                                                         3944.77
                                                                                                                                     4635.49
                                                                                                                                                 5326.21
                                                                                                                                                                         44.1899
                                                                                                  2512.50
                                                                                                                                                                                      7365.38
                                                               753.85
                                                                          1095.09
                                                                                                              3228.64
                                                                                                                                                              6006.97
                                                   HEIGHT RANGE
                                      12.000 MC
                                                               140.00
                                                                          187.17
                                                                                                             112.74
                                                                                      100.00
                                                                                                                                     110.83
                                                                                                                                                              110.00
                                                                                                                                                                                     109.73
                                                                                                                                                  •
                                                                                                  •
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7744.43

150.00

6137.81

100.00

•

6819.16 7218.02 7593.56

140.00

SEL-63-103

PATH LENGTH	1 8045.35 KM TX LAT 19.50 DEG	PATH LENGI	5.35 KM TX LAT 19.
MODE .F2	.F2 .F2 .F2 .F2 .F2 .F2	M00E .F2	.f2 .f2 .f2 .f2 .f2 .f2 .f2
12.000 MC	20.904 DEGREES	12.000 MC	23.913 OFGREES
HE I GHT	RANGE	HEIGHT	RANGE
140.00	335.66	140.00	293.76
170.63	437.73	173.20	398.68
150.00	517.86	150.00	464.11
100.00	630.00	100.00	563,39
ė	875.45	•	797.36
140.00	1221.76	140.00	1091.12
192.09	1437.13	195.22	1284.51
150.00	1630.90	150.60	1458.78
100.00	1755.06	100.00	1564.10
•	2000.51	•	1760.07
140.00	2349.05	140.00	2082.37
185.51	2566.21	192.95	2280.54
150.00	2761,59	150.00	2459.57
100.00	2887.79	100.00	2568.11
;	3133.23	ċ	2762.07
140.00	3483.69	140.00	3065.53
172.86	3687.70	182.28	3270.43
150.00	3869.37	150.00	3435.88
100.00	3997.23	100.00	3545.43
ė	4242.68	•	3759,39
140-00	4594.63	140.00	4063.79
182.54	4833.54	181.43	4253.98
150.00	5050.80	150.00	4424.74
100.00	5179.98	100.00	4535.11
•	5425.43	•	4749.08
140.00	5778.50	140.00	5054.20 140.00 6102.78
203.42	6074.58	193.38	5272.78 211.32 6361.74
150.00	6344.59	150.00	5472.17 150.00 6601.58
100.00	6479.62	100.00	5583.17 100.00 5712.95
•	6725.06	·	5797.13 6926.92
140.00	7078.75		140,00 7232.82
205.60	7302.56		208.56 7484.94
150.00	7664.54		150.00 117.57
100.00	7794.14		100.00 7828.99

50.26 DEG

	TX LONG -154.95 DEG RX BEARING 50.26 DEG																							
6 OCTOBER 1962 1737.36 GMT PAHDA/BEOFORO PATH	19.50 OEG																							
GMT PAHDA	TX LAT	F2	EGREES																					
1962 1737.36	PATH LENGTH 8045.35 KM	.F2 .F2 .F2	9.659 DEGREES	RANGE	625.52	825.41	989.93	1199.92	1674.83	2328.72	2663.34	2962.70	3181.45	3656.36	4318.01	4680.38	5007.72	5232.91	5707.82	6374.27	6873.11	7337.97	7565.72	8040.63
6 OCTOBER	PATH LENGTH	100E .F2	17.000 MC	HE I GHT	140.00	182.75	150.00	100.00	•	140.00	165.03	150.00	100.00	•	140.00	181.36	150.00	100.00	ò	140.00	213.76	150.00	100.00	•
	RX BEARING 50.26 DEG																							
	EARING																							
	×																							
	930 89.481- 340 - 71																							
	930 89.481- 340 - 71			REES																				
	GMT PAHOA/8EOFORU PATH		MODE .F2 .F2 .F2	6.286 OEGREES	HEIGHT RANGE	795.34	1164.93	1494.02	1755.57	2376.09	3229.29	3636.69	4901.77	4285.17	4905.69	5717.34	6457.01	150.00 7109.07	7405.51	8026.02				

```
RX BEARING 50.26 DEG
       TX LCNG -154.95 0EG
6 OCTOBER 1962 1737.36 GMT PAHOA/BEOFORO PATH
         PATH LENGTH 8045-35 KM TX LAT 19-50 DEG
                    HOOE .F2 .F2 .F2 .F2
                            13.565 DEGREES
                                                                                                                                                                                                                                                                 7678.85
                                                                                                                                                                                                                                                                          8043.77
                                                                                                                                                                                                                            6226.78
                                                                                                                                                                                                                    5861.86
                                                                                                                                                                                                                                                        7502.65
                                                                                                                                                                                        5046.28
                                                                                                                                                                                                                                     6737.86
                                                                                                                                                                                                                                              7135.07
                                                                                                                                                                                                 5380.85
                                                                                                                                                                                                           5686.20
                                                                                                                                                             3997.72
                                                                                                                2455.21
                                                                                                                                  2991.36
                                                                                                                                            3498.91
                                                                                                                                                     3763.34
                                                                                                                                                                       4171.58
                                                                                                                                                                               4536.50
                                                                                                       2178.60
                                                                            1003.83
                                                                                    1368.75
                                                                                              1873.05
                                                                                                                         2626.44
                                                                   836.21
                                                 490.10
                                                          678.10
                                      HEIGHT RANGE
                                                                                                                                                                                                                                                                 100.00
                                                                                                                                                                                                                                                217.70
                                                                                                                                                                                                                                                         150.00
                                                                                                                                                              150.00
                                                                                                                                                                                                                     100.00
                                                                                                                                                                                                                                     140.00
                                                                                                                                                                                                           150.00
                              17.000 MC
                                                                                                                                                                                        140.00
                                                                                                                                                                                                 198.22
                                                                                                                                             140.00
                                                                                                                                                      178.86
                                                                                                                                                                                                                              •
                                                                                                                          100.00
                                                                                                                 150.00
                                                                                                        197.43
                                                                                              140.00
                                                                                                                                                                                 .
                                                                             100.00
                                                          181.88
                                                  140.00
                                                                    150.00
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